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REPORT OF THE MEETING OF A GROUP OF EXPERTS ON TUNA STOCK ASSESSMENT

(under the FAO Expert Panel for the Facilitation of Tuna Research)

Miami, U.S.A., 12-16 August 1968

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1968

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PREPARATION OF THIS REPORT

This is the final version of the draft report prepared during the meeting, and amended by correspondence between the members.

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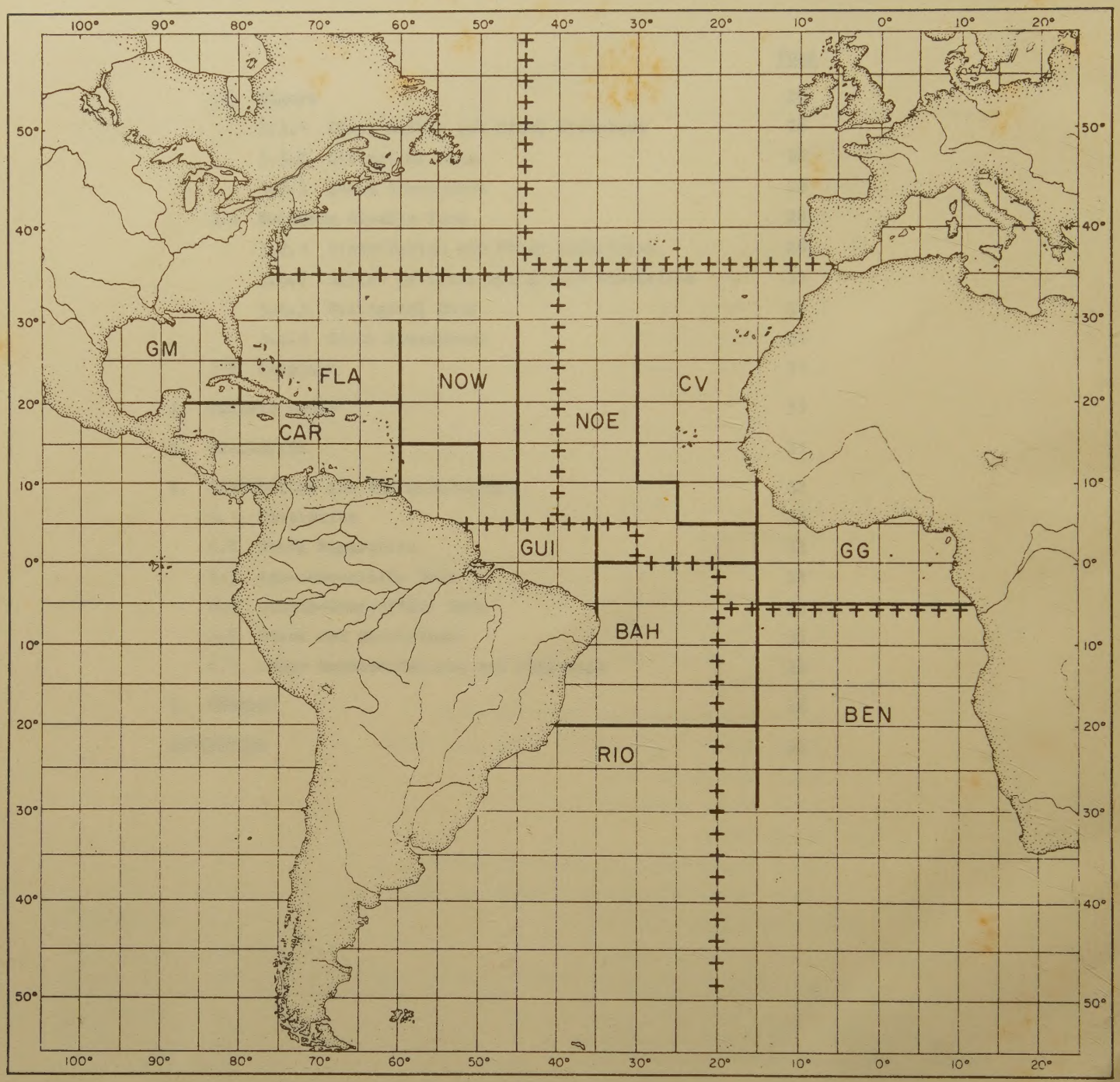

Figure 1 – Statistical areas used in the study of Atlantic tunas

1. INTRODUCTION

Recently the declines in catch rates of some species of tuna in the long-line fisheries in both the Atlantic and Indian Oceans have raised concern about the stocks of tuna in these areas. Two new bodies - the International Commission for the Conservation of Atlantic Tuna, and the Indian Ocean Fishery Commission - which are wholly or partially concerned with the state of the stocks of tuna, are due to come into operation soon. However, neither body has as yet (August 1968) held its first session, and because it may take some time for them to make arrangements for the provision of scientific advice, while the tuna stocks may be continuing to decline, FAO believed that some interim arrangements were urgently required. The meeting of experts here reported was therefore convened under the auspices of FAO's Expert Panel for the Facilitation of Tuna Research to review the available scientific information concerning the state of stocks, and to advise on the requirements (research, statistics, etc.) for improved knowledge of the state of the stocks*.

The meeting was held from 12 to 16 August at the Tropical Atlantic Biological Laboratory of the Bureau of Commercial Fisheries, Miami, U.S.A., by the kind invitation of the Director. A list of those attending is given in Appendix 2.

During the meeting, the main species considered were yellowfin (Thunnus albacares), albacore (T. alalunga), bluefins (T. thynnus and T. maccoyi), bigeye (T. obesus) and skipjack (Katsuwonus pelamis). The billfishes were not considered, though they are important to the longline fishery at some times and places, and the state of their stocks should be examined as soon as practical. The main attention was given to the Atlantic, since the state of the stocks in the Indian Ocean has recently been reviewed (see FAO Fisheries Reports No. 54) by a group of experts set up by the Indo-Pacific Fisheries Council. The group noticed that there were many similarities in the distributions and states of exploitation of the different species in the two oceans, and indeed also in the Pacific Ocean.

2. ATLANTIC

2.1 General

For statistical and other areas the Atlantic Ocean has been divided into areas in several ways. Two such divisions are shown in Figure 1. This shows, in full lines, the areas used for studies of the Japanese long-line statistics by Le Guen and Wise (in press); the broken line shows the areas used by FAO for general fishery purposes. These latter agree in the North Atlantic with the boundaries of the International Commission for the Northwest Atlantic Fisheries, and of the statistical area (North) of the International Council for the Exploration of the Sea; in the South-east Atlantic they agree with the proposed boundaries of the new Commission.

2.2 Yellowfin Tuna

2.2.1 Distribution and Stock Separation (see Figure 2)

The general form of the distribution of yellowfin tuna in the Atlantic is shown in Figure 2. There are two centres of high apparent abundance. These are indicated by high catches per unit effort in the longline fishery off northern South America (statistical areas GUI, CAR, BAH, see Figure 1) and off tropical West Africa (GG, CB, NOE, BEN). These two centres of high apparent abundance suggest that there may be at least two groups of yellowfin tuna in the Atlantic Ocean. Some suggestion of differences in the rates of decline in longline catch per unit effort with time between the eastern and western centres also suggests a separation between eastern and western groups of yellowfin tuna. The pattern of change in catch per unit effort in the statistical area now is perhaps different from either east or west, and this may possibly be an area of mixing. Considerations of yellowfin tuna larval distribution and gonad studies have not, as yet, indicated any clear differences between the centres of high catch per unit effort, though preliminary studies at the Miami Laboratory of the larval distribution tend to support the hypothesis of eastern and western groups.

A relation between the fish exploited in the surface fisheries off West Africa and the fish taken in the longline fishery may be revealed by the correlation between the catches per unit effort in the long-line fishery in areas to the north of Senegal (CV and GG) and the catch per unit effort in the Senegal

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* See Report of the third session of FAO's Committee on Fisheries (FAO Fisheries Reports No. 58), paragraphs 41, 42.

Figure 2 - General distribution of yellowfin tuna in the Atlantic
(darker shading denotes higher apparent abundance)

Table 1. Yellowfin tuna - estimated total catches in the Atlantic (thousand tons)

	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
Cuba	...	...	...	...	...	...	...	1.7	0.9	0.8	0.8	...
China (Taiwan)	-	-	-	-	-	-	-	0.4	0.3	0.1	0.9	2.2
France	...	...	9.2	9.6	13.3	12.6	14.2	21.8	21.4	16.8	18.8	20.8
Japan - surface	-	-	-	-	-	-	1.1	0.9	2.8	3.7	5.6	...
- longline	ø	10.4	29.8	43.9	46.4	38.7	38.5	36.3	38.4	37.3	15.8	...
Korea	-	-	-	-	-	-	-	-	-	...	2.9	4.4
Senegal	-	-	-	-	-	-	-	-	-	0.2	1.4	3.1
Spain	...	...	...	...	...	...	...	...	2.8	3.0	12.3	...
Venezuela	-	0.6	0.9	1.6	2.1	2.0	3.6	3.1	1.9	1.8	2.1	2.1
Surface fisheries	-	-	9.2	9.6	13.3	12.6	15.3	22.7	27.0	23.7	38.1	...
Longline fisheries	-	11.0	30.7	45.5	48.5	40.7	42.2	41.5	41.5	40.0	22.5	...
Total	-	-	39.9	55.1	61.8	53.3	57.5	64.2	68.5	63.7	60.6	...

Notes

(a) Statistics of France and Senegal adjusted to eliminate double reporting. Entries for France include all landings by French vessels, whatever the port of landing. Entries for Senegal include only landings by local vessels.

(b) Reported 'yellowfin' catches for France have been assumed to be 80% yellowfin and 20% bigeye and skipjack

(c) Reported catches of 'various tunas' by Spain off West Africa have been taken to be 60% yellowfin and 40% skipjack

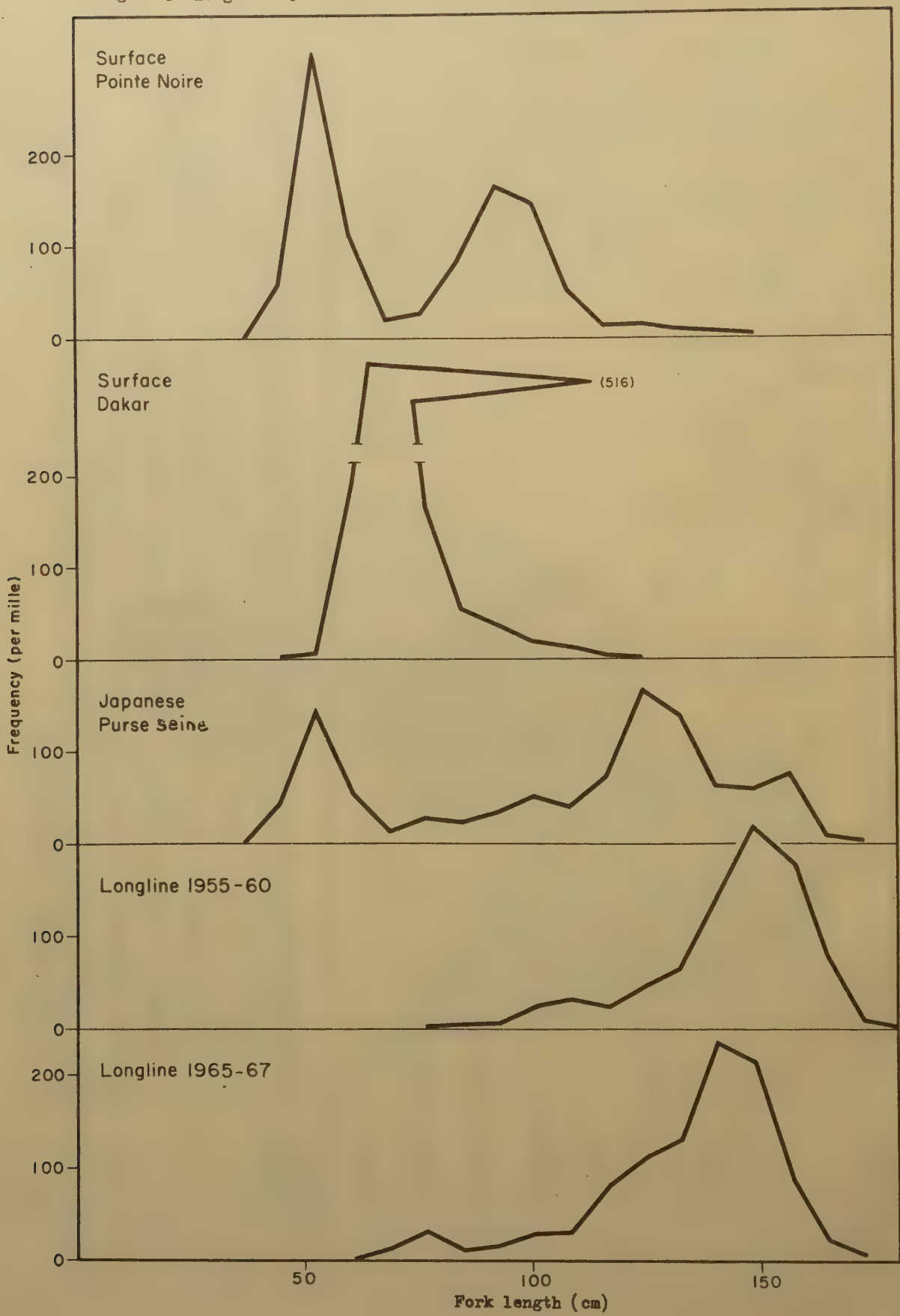
(d) Fisheries of France, Senegal and Spain are taken as all surface fisheries
Fisheries of Korea, China, Cuba and Venezuela are taken as longline fisheries

(e) Small quantities were taken by other countries - not specified in the table

(f) The species composition of the Korean catches was estimated to be the same as the Japanese

(g) ø denotes quantities less than 100 tons ... denotes no information - denotes zero catches
brackets denote estimated figures

Figure 3- Length composition of tuna caught in the Atlantic yellowfin fisheries



surface fishery, though as noted below confusion between yellowfin and bigeye may have made the catch per unit effort in the surface fishery misleading. In summary, using distribution of catch per unit effort as an index of stock separation there is some evidence of at least two yellowfin stocks, in the east and west Atlantic, and these areas have been treated separately in some of the subsequent analyses.

However the available data are not sufficient to warrant firm conclusions concerning the stock structure.

The group is of the opinion that the stock structure of yellowfin tuna is of fundamental importance to understanding the dynamics of the yellowfin in the Atlantic Ocean. It recommends therefore that strong consideration should therefore be given to the immediate application of techniques of studying stock separations such as (for example) tagging and morphometrics and possibly also biochemical studies of infraspecific variation.

2.2.2 Review Statistics of Catch and Effort

The estimated catches of yellowfin tuna in the Atlantic, are shown in Table 1. This table is based on tabulations of statistics submitted to FAO, with corrections for some of the errors (e.g. double reporting both by country of landing, and by flag country of the fishing vessel) in these figures known to members of the group, as discussed in detail in the section on statistics.

The group was of the opinion that the problem of obtaining accurate statistics has not been given sufficient attention by the fishing countries and that this problem requires additional effective action to provide the basis for analysis of tuna dynamics. The group believes that obtaining accurate current statistics (and the necessary revision of past statistics) can only be effectively achieved by a competent man visiting the relevant fishing ports.

Size composition

Honma and Hisada (1968) gave the length composition of catches by fishing area and fishing gear. The yellowfin tuna caught by longline are large fish, see Figure 3. The fish caught in the centre of high apparent abundance off South America (GUI) tend to be smaller than those to the east. In addition, the yellowfin in the eastern Atlantic areas tended to increase in size with distance from the African coast. The surface fisheries prosecuted off the west coast of Africa usually take smaller fish. One of these inshore surface fisheries (Dakar area) apparently takes only a single size group, yet another surface fishery (Pointe-Noire) takes two size groups (Figure 3, top curves). The Japanese purse seine fishery, which tends, however, to operate more in the offshore areas and uses slightly different gear takes larger fish than the inshore surface fisheries (Figure 3, middle curve).

2.2.3 Biological Data

Table 2. Examples of Growth Curves

	L_∞	K	Size range of samples
Yang, et al. (M.S.)	223	0.25	70-155 cm
Le Guen and Champagnat (1968) (Pointe-Noire Sample)	166	0.54	62-151

Several growth curves were presented. The parameters of the von Bertalanffy growth function for two of these curves are given in Table 2. Though these sets of parameters appear quite different, the resultant curves do not differ appreciably over the important range from 60-150 cm (Figure 4).

2.2.4 Stock Assessment, General

The general problem of the dynamics of the yellowfin tuna in the Atlantic Ocean was reviewed from a consideration of: (1) the effect of fishing in the longline fishery; (2) the effect of fishing in the surface fishery; (3) the effect of the surface fishery on the number of recruits entering the longline fishery (at about 100 cm); and (4) the effect of depletion of the spawning stock by the surface and the longline fisheries on the total recruitment to both fisheries.

Figure 4 - Examples of growth curves for Atlantic yellowfin tuna

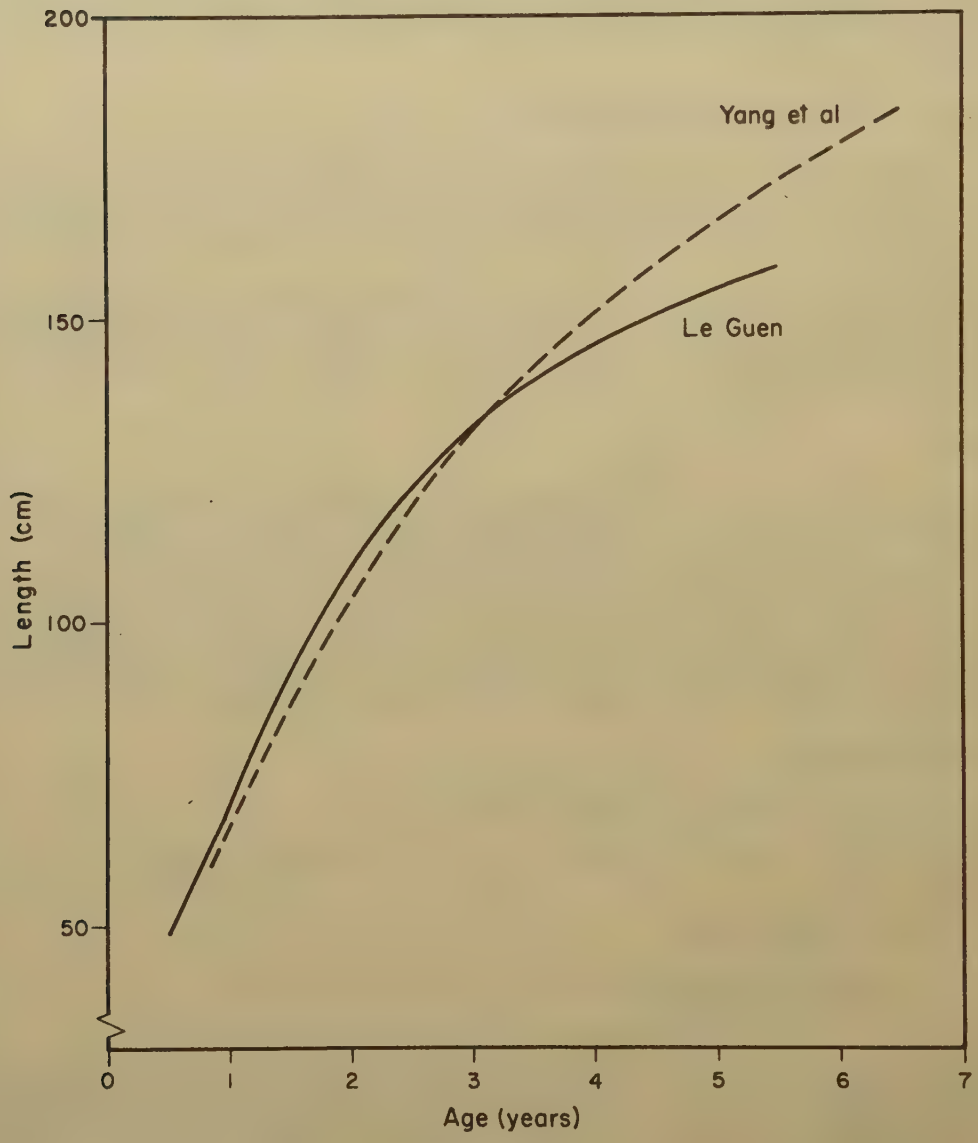


Figure 5 - The relations between c.p.u.e. and fishing effort for yellowfin tuna (a) in the Eastern Atlantic, (b) in the Western Atlantic, and (c) in the Atlantic as a whole

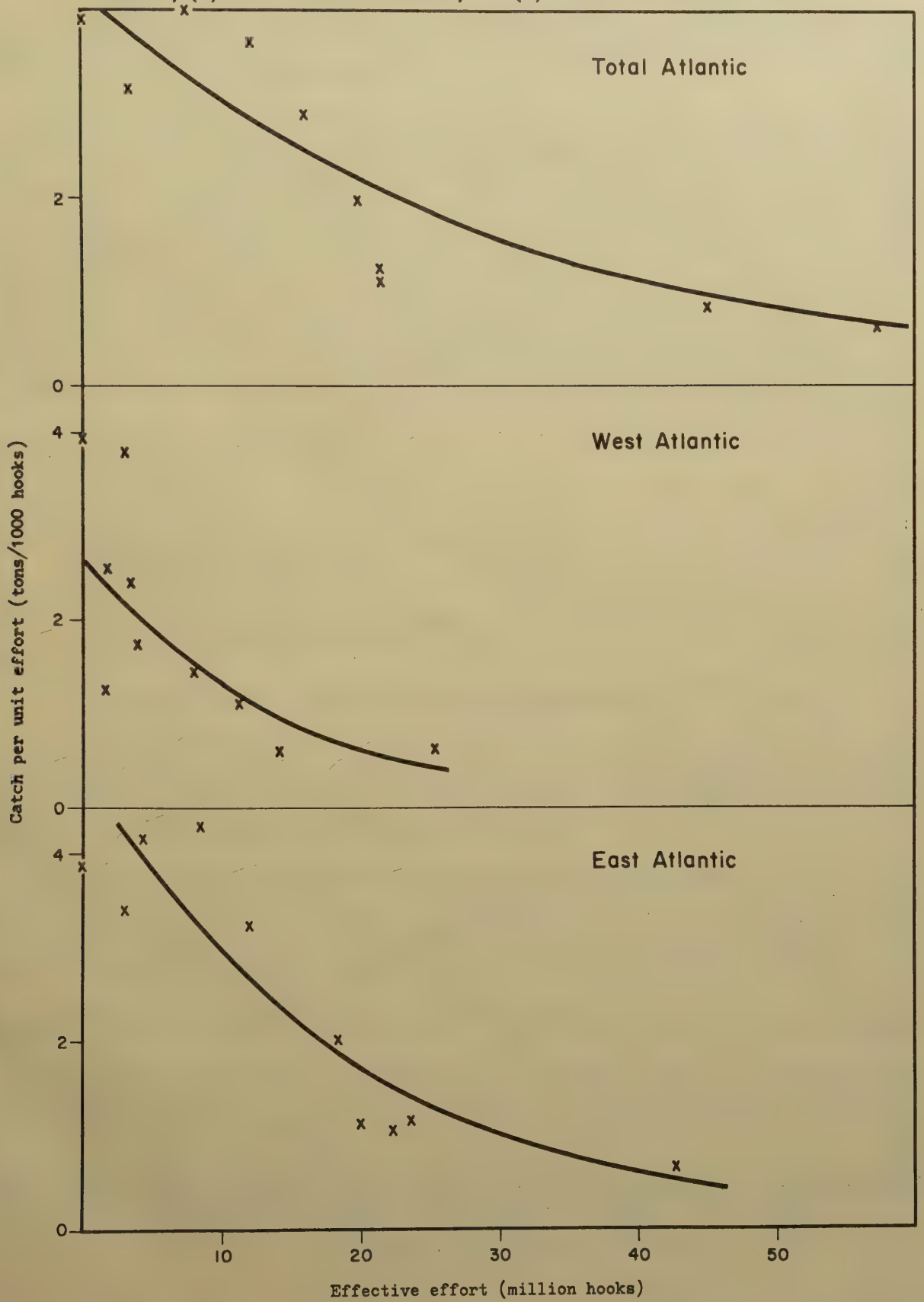
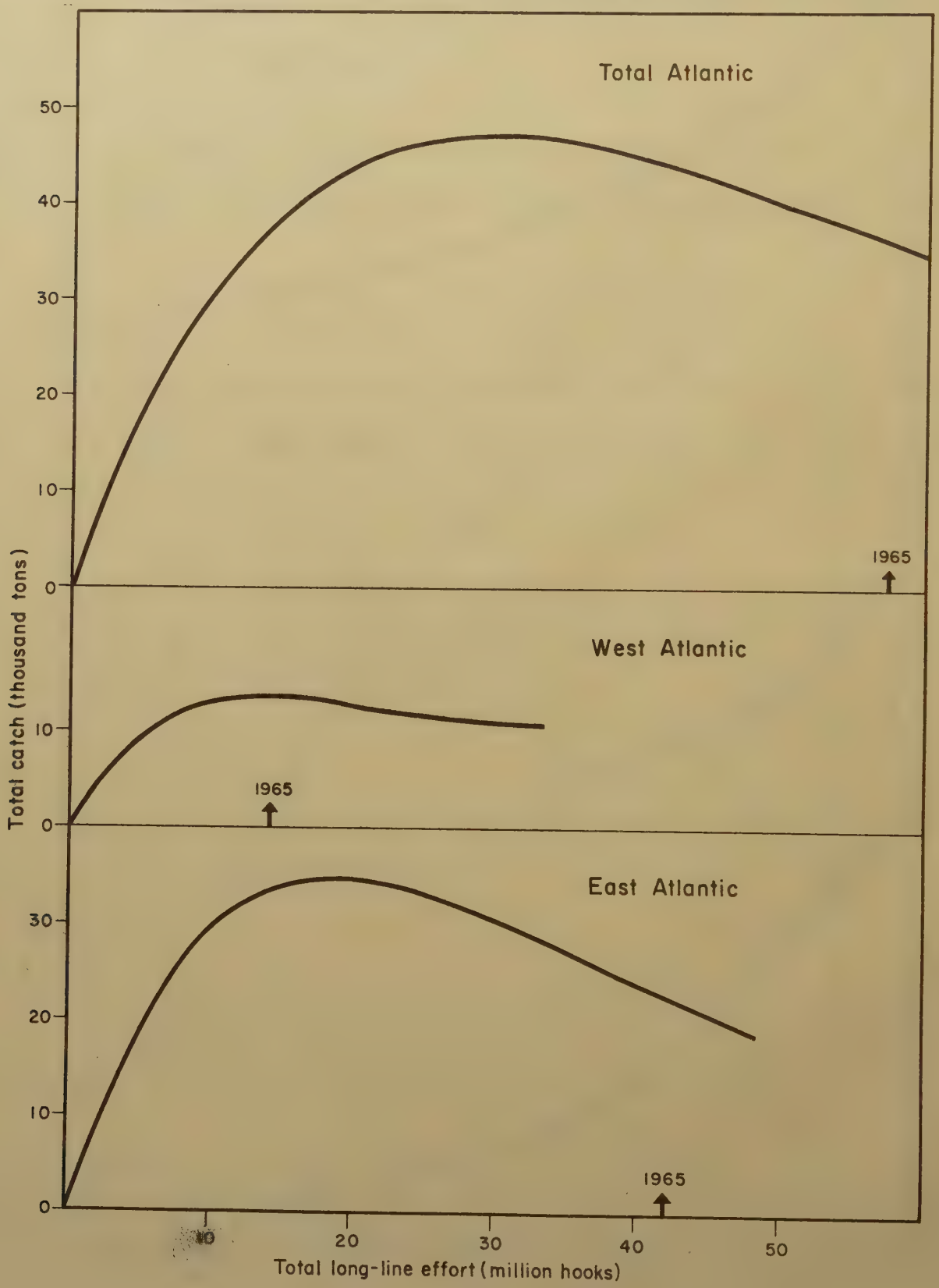


Figure 6 - Possible relations between sustained catch and fishing effort for yellowfin tuna, as deduced from the curves in Figure 5



2.2.5 The Effect of Fishing in the Longline Fishery

In accordance with the tentative assumptions regarding stock separation, studies were made for the east and west Atlantic, as well as for the Atlantic longline fishery as a whole. For each area the catch per unit effort, and total effort were calculated; the relations between these variables are shown in Figure 5.

This figure shows that in both areas there has been a large decrease in catch per unit effort, associated with increased fishing effort. The relation appears to be non-linear. Using the curved lines drawn in the figures obtained by fitting a linear relation between effort and the logarithm of c.p.u.e., to derive one of the possible empirical relations between catch per unit effort and effort, the relations between catch and effort can be deduced, which are shown in Figure 6. These figures should be interpreted with some caution for several reasons. First, there are the usual dangers associated with the correlation of time series over a short period of time, especially when both variables (effort, and catch per unit effort) are changing monotonously. Second, the catch per unit effort in one year will be related not only to the effort in that year, but to the effort in several years previously, for a duration equal to the lifespan of the individual fish in the fishery. Third, the analysis of section 2.2.7 suggests that the surface fishery has reduced the recruitment to the longline fishery, and that this reduction has been greater in recent years, corresponding to the increase in surface fishing. Thus in these years, which are also the years of high longline effort, the catch per unit effort in the longline fishery will be lower than it would be in the absence of the surface fishery, so that the reduction due to the longline fishery will tend to be exaggerated.

Despite these reservations regarding the quantitative interpretation of Figures 5 and 6, qualitative conclusions can be drawn.

(i) The catch per unit effort of yellowfin in the longline fishery has been reduced by fishing.

(ii) Any further increase in longline fishing would at best increase the total longline catch only marginally, and might possibly decrease it; the catch per unit effort will certainly be decreased.

(iii) It is possible that a moderate decrease in the total longline fishing effort would tend to give some increase in the total longline catch. The catch per unit effort would certainly be increased.

2.2.6 The Effects of Fisheries on the Surface Stocks

The longest series of data available are those published by Champagnat (1968). These represent the years 1955 to 1967 in the Dakar fishery, and indicate a clear decline in the catch per unit effort over the study period. Another series of data given in Le Guen et al., (1968) for the year 1964 through 1967 for the Pointe-Noire fishery, however, show no decrease in catch per unit effort (Figure 7). Also Honma et al. (1968) gave various series of catch per unit effort in surface fisheries, including Pointe-Noire, none of which showed any decrease.

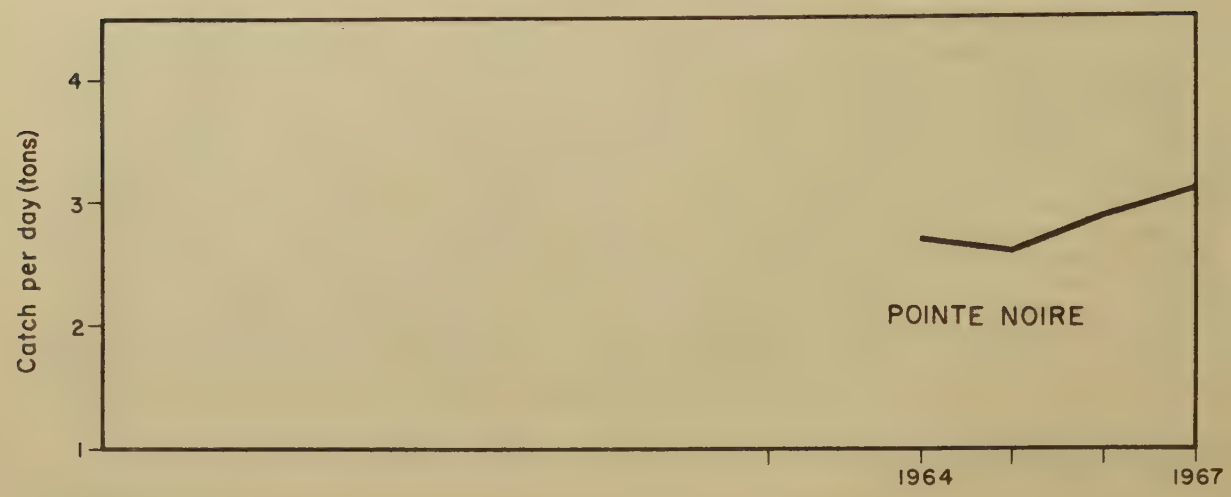
There is some problem in the Dakar fishery concerning the identification of bigeye and yellowfin. The reported landings of each species, and of skipjack are given in Table 7 of Champagnat (1968), which shows that up to the 1962-63 season no bigeye were reported, but that in later seasons bigeye vary between 0 and 48% of the total reported catch. It is known that in the early seasons the buyers were unwilling to purchase bigeye, but that in more recent years no distinction has been made between bigeye and yellowfins, small bigeye being included in the nominal catches of yellowfin.

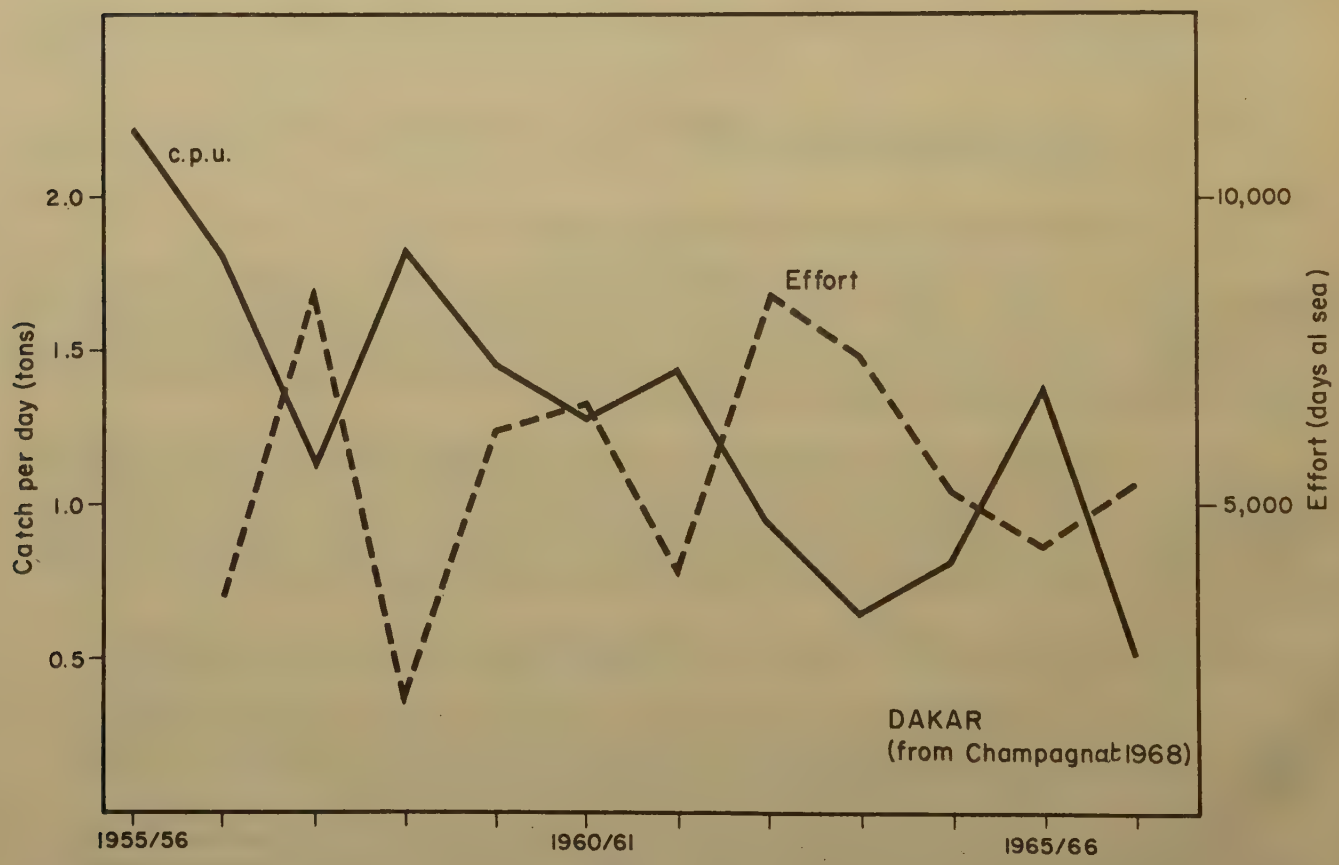
The group, therefore, concluded that while there probably has been a decline in abundance of yellowfin off Dakar, the figures of catch per unit effort should be treated with some caution.

The estimated fishing effort in the Dakar area is also given in Figure 7. This shows no clear trend, and suggests that the presumed decline in the abundances of surface yellowfin is not due simply to the effect of the surface fishing. The data for the more southern fishery from Pointe-Noire do not extend over a long enough period to draw any clear conclusions.

The fishing rate in the surface fishery can be estimated indirectly, if the effect of the surface fishery on the recruitment to the longline fishery, as estimated in the following section, is accepted and if the recruitment to the surface fishery is constant. That is, if

Figure 7 - Catches per unit effort of yellowfin tuna in two surface fisheries of the Eastern Atlantic





p = fractional reduction in longline recruitment

T = time during which the fish are in the surface fishery

F = fishing mortality coefficient in the surface fishery

then $p = 1 - e^{-FT}$

so that, taking p = 0.5, T = 1.5, then 1.5 F = 0.69, F = 0.46. If the natural mortality of the smaller yellowfin is high (e.g. around 0.8 as in the eastern Pacific), this value of F would suggest a moderately high fishing rate, but not so high that some increase in catch could not be achieved by a further moderate increase in fishing effort. (For example using the constant parameter model, if $\frac{F}{M} = 0.55$, and taking $\frac{M}{K} = 1.5$, $\frac{l_c}{L_\infty} = 0.30$ - from Le Guen's growth curves - then the biggest catch would be taken with double the effort, and would be about 12% above the present level).

The group believes that the above calculations provide no more than a general qualitative estimate of the effect of fishing, and that better quantitative estimates are urgently required. Until such improved estimates are obtained, caution should be shown in allowing any large increase of fishing effort in the surface fisheries.

2.2.7 The Effect of the Surface Fisheries on Longline Recruitment

Possible changes in the recruitment into the longline fishery may be detected from the analysis of the catch and effort data. Thus the steady state relation:

$$C = R \times \frac{F}{(F + M)} = R \times \frac{qf}{(qf + M)}$$

where

C = catch in numbers

R = number of recruits into the longline fishery

F, M = coefficients of fishing and natural mortality

f = fishing effort

q = constant

can be written as:

$$\frac{f}{C} = \frac{1}{R} \frac{qf + M}{q} = \frac{1}{R} f + \frac{M}{qR}$$

i.e., the plot of $\frac{f}{C}$ against f should, if R, q and M are constant, be linear with slope $\frac{1}{R}$ and deviations from linearity can be taken as suggestions of changes in R, though changes in the other parameters can also cause non-linearity. If this plot is done separately for the longline fishery of the east and west Atlantic, the data for the west Atlantic can be adequately fitted by a straight line, whereas that for the east cannot - the points for the later years lying above the line through the earliest years, suggesting a higher value for $\frac{f}{C}$, and a lower recruitment, though it should be noted that the steady state relations of the above equations do not apply exactly to the Atlantic fishery in which the effort has been steadily increasing.

A quantative estimate of the annual recruitment can be obtained by dividing the catches by the estimated exploitation rate $(\frac{F}{F + M})$, i.e.

$$R = C \times \frac{(F + M)}{F} = C \times \frac{f + \frac{M}{q}}{f}$$

and one estimate of $\frac{M}{q}$ is provided by the intercept on the x-axis of the above plot. If the exploitation rate is high, the precise value of $\frac{M}{q}$ used does not affect the estimate much.

Using this method, and estimates of $\frac{M}{q}$ of 12 million hooks in the east, and 6 million in the west, estimates of recruitment were obtained. In the west Atlantic, apart from a high value in 1958, these vary around 400,000 fish with no obvious trend. In the east Atlantic there is a clear decrease from around 1.6 million fish in 1957-61 to around 0.9 million fish in 1962-65, with the most obvious decrease occurring between 1960 and 1962.

Qualitatively this supports the idea that the surface fisheries, which are virtually confined to the eastern Atlantic, are reducing the recruitment to the longline fishery on that side of the ocean. However, the timing of the decline in the estimated recruitment does not agree too well with the increase in the surface fisheries, which are biggest after 1961, and would, therefore, be expected to cause the biggest reduction to the longline recruitment after about 1963.

The effect of the surface fishery can also be estimated from the numbers caught, if the natural mortality is known. For a given recruitment to the surface fishery, the reduction in the recruitment to the longline fishery is equal to the catch in the surface fishery, less the numbers which would even in the absence of a surface fishery, have died before recruiting to the longline fishery, i.e.

$$C_s e^{-MT}$$

where C_s = surface catch in numbers

T = differences between the age of recruitment to the longline fishery, and the average age in the surface fishery

Taking T = 2 years

M = 0.8 (based on the estimates for yellowfin in the eastern Pacific)

and average weight in the surface fishery = 10 kg, and a surface catch of 30,000 tons, then

C_s = 3.0 million

and the reduction in the longline recruitment

= 0.6 million

This agrees quite well with the reduction estimated from the longline catch and effort data. It may be noted that if at the present high fishing rate, the proportion of fish recruiting to the longline fishery which are caught in the fishery ($= \frac{F}{F+M}$) is about 75% and the average weight ($\bar{W}$) is 40 kg, then the reduction in the longline catch is 0.6 x 0.75 x 40 = 18 thousand tons, i.e., less than the surface catch.

This conclusion, of course, depends on the values of the parameters - T, M, $\frac{F}{F+M}$ and $\bar{W}$ - used in the calculations. Increasing values of T, M, and decreasing values of $\frac{F}{F+M}$ and $\bar{W}$, will tend to decrease the estimated loss to the longline catch. The results of calculations using some other possible combinations of parameters are set out in Table 3 below.

Table 3. Estimates of the effect on the longline and total yellowfin catch of a surface fishery taking 30 million fish (30,000 tons)

T	2	2	2	1.5	1.5	1.5	2	2	1.5
M tons	0.8	1.0	0.6	1.0	0.8	0.6	0.8	0.8	0.6
$\frac{F}{F+M}$	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.6	0.75
$\bar{W}$	40	40	40	40	40	40	45	40	30
Loss to longline fishery ('000 tons)	18.2	9.7	27.2	20.2	27.2	36.6	20.4	14.5	27.5
Change in total catch (tons)	11.2	20.3	2.8	9.8	2.8	-6.6	9.6	15.5	2.5

The actual values are very variable, but only with a combination of low natural mortality and a small time interval between the two fisheries (which is likely to coincide with a lower value of

$\bar{W}$, as indicated in the last column), will the loss to the longline fisheries be larger than the surface catch. This agrees with other theoretical calculations in terms of yield per recruit, that over most of the probable range of values of natural mortality and growth, the optimum size at first capture, even at high fishing rates, is less than the size at recruitment to the longline fishery.

The present data, therefore, suggest that:

(i) the surface fishery reduces the recruitment to and catches of, the longline fishery;

(ii) the loss to the longline catch due to this reduction in recruitment is probably less than the surface catch.

The group noted that there is a tendency in at least some elements of the surface fishery for the minimum size of fish landed to decrease. Theoretical calculations show that for probable values of the parameters of growth and mortality, the optimum size at first capture is not less than the present size at recruitment (2-3 kg), i.e. if considerably smaller fish are taken in the surface fishery, this is likely to lead to a loss in total catch, and perhaps also to a loss on the catch by the surface fishery. Noting also that it is much easier to prevent the size of first capture being reduced, then to increase it once the fishermen are used to catching small fish, the group therefore recommended that action should be taken to prevent yellowfin smaller than 3 kg being taken in the surface fishery at least until better assessments are available. These may in fact show that an even larger minimum size is desirable.

2.2.8 Spawning Stock and Recruitment

An essential element in the consideration of the effect of fishing on the stocks is the nature of the relation between stock and recruitment. If, for example, high levels of stock produce low recruitment, then a population that is lightly fished might not produce the greatest possible number of recruits to the fishery. In general, the nature of the relationship between stock and recruitment is not known. Several theoretical models have, however, predicted the nature of such a relation. One is the dome-shaped stock-and-recruitment curve. Another is the asymptotic curve. The dome-shaped curve predicts that high levels of stock size will produce a diminution in recruitment while the asymptotic model predicts that recruitment is essentially independent of stock size at high levels of stock (which may or may not include all levels of stock occurring at practicable levels of fishing intensity). These two formulations become relevant to the management of fisheries when yield per recruit relations are considered because changes in yield per recruit are the same as changes in yield only when the stock size is sufficiently large to be in the asymptotic region of the asymptotic model or is restricted to a small range near the maximum region of the dome-shaped model. Since neither relationship is obtained with certainty in most fisheries, the question of the nature of this relation must be held in abeyance.

A correlation has been observed (Champagnat, 1968) between the catch per unit effort in the longline fishery off Dakar (which is a measure of the spawning stock) and the catch per unit effort in the surface fishery in the same area one to two years later. This suggests that the relation for this stock is such that, at the present level, any reduction in spawning stock (e.g. by increased fishing in either the surface or longline fishery), will cause an almost proportional reduction in recruitment. The group did not believe that the evidence was at all conclusive, but if the true relation is at all close to this, there would be an urgent need to ensure that the spawning stock was not further reduced. In other areas the group had no evidence concerning the stock - recruitment relation. In general, the group believed that the resolution of the stock recruitment relation was of prime importance in understanding the effect of fishing, and advising on possible management, and urged that everything shall be done that might help solve the problem.

In summary it appears:

(i) the fishing has greatly reduced the catch per unit effort in the longline fishery;

(ii) any increased longline fishing would at best increase the longline catch marginally, and might decrease it;

(iii) the evidence of a general decline in catch per unit effort in the surface fisheries is not striking;

(iv) the surface fishery has reduced the recruitment to the longline fishery;

(v) if the size of fish caught in the surface fishery does not decrease, then the presence of this fishery will probably tend to increase the total catch;

(vi) the nature of the stock-recruitment relation can critically effect the impact of fishery in the stocks. The relation is not known at present, and should be investigated by all means possible.

2.3 Albacore Tuna

2.3.1 Distribution and Stock Separation (see Figure 8)

Catch statistical data for the Japanese longline fishery was presented which showed that albacore were distributed widely throughout the Atlantic Ocean from about 45°N to 40°S. The surface fisheries in the northern waters from Morocco to the Bay of Biscay take large quantitites of albacore, but very few are taken in the surface fisheries in tropical waters. These data also showed a general absence, or very low catches, of fish along the Equator, suggesting a division of the Atlantic Ocean albacore into a northern and southern group. Morphometric data, although few, tended to support this view.

In the northern group average size tended to increase in a southerly direction, i.e. towards the Equator. In the southern group average sizes tended to decrease in a southerly direction, i.e. away from the Equator. The southern fish ranged in size from 80 to 115 cms north of 25°S, while south of this latitude the range is about 55 to 100 cms. Offshore of southwest Africa small immature albacore are caught throughout the year. There is some evidence that small albacore may intermingle between the Atlantic and Indian Ocean.

In summary, there was some evidence, although very meagre, to indicate that the albacore could be divided into a northern and southern component and that the southern component possibly intermingles between the Atlantic and Indian Oceans. It is the opinion of the group that the new Atlantic Tuna Commission, and the Indian Ocean Fisheries Commission should take the intermingling of fish between the two oceans into account in their programmes of work, and should pursue actively the continued study of this interchange. It is also important to continue the study of the population structure in the Atlantic by tagging, morphometrics, and other means.

2.3.2 Review Statistics of Catch and Effort

The group considered catch statistics compiled by FAO and from various sources on the Japanese longline fleet. These statistics, as amended during the meeting, are shown in Table 4.

Table 4. Estimated catches of Albacore in the Atlantic (thousand tons)

	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
France	18.1	22.8	20.9	20.9	20.6	18.2	21.6	17.3	20.8	16.6	14.3
Japan	ø	0.6	1.8	6.2	7.9	7.4	19.0	21.8	39.8	31.8	28.5
Portugal	-	-	-	-	-	-	-	-	1.9	5.8	1.0
Spain	...	...	28.9	26.7	25.9	19.9	22.3	28.4	16.6	29.0	25.6
Total surface	(45)	(50)	49.8	47.6	46.5	38.1	43.9	47.5	39.3	51.4	40.9
Total longline	ø	0.6	1.8	6.2	7.9	7.4	19.0	21.8	39.9	31.9	31.1
Total	(45)	(50)	51.6	53.8	54.4	45.5	62.9	67.5	79.2	83.3	72.0

Notes (a) Reported figures for some South American countries are believed to refer to landings by Japanese vessels in these countries, and have been omitted

(b) Totals include longline catches by Korea and China

For further notes see Table 1

Figure 8 - General distribution of albacore in the Atlantic
(darker shading denotes higher apparent abundance)

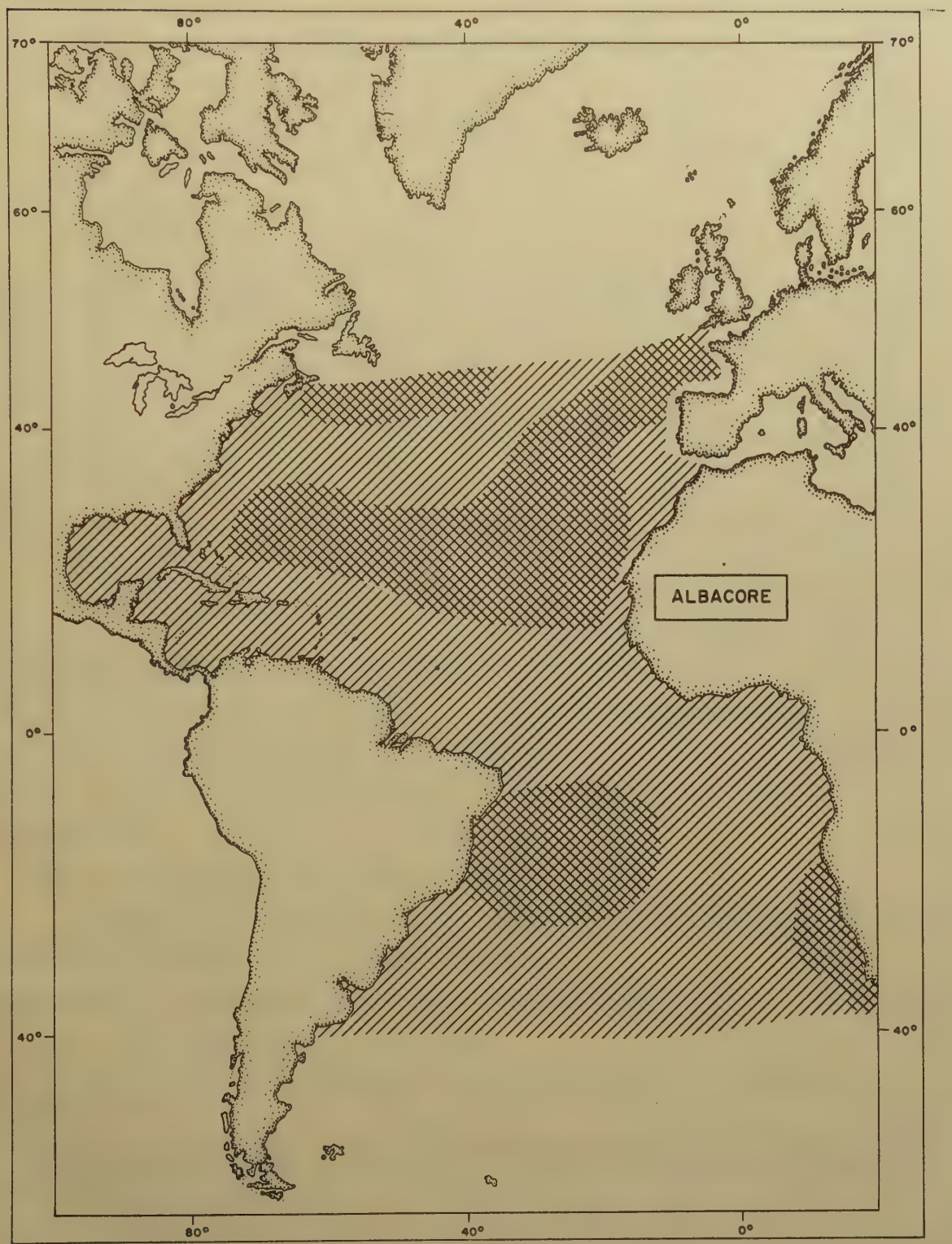


Figure 9 - Catches per unit effort of albacore by Japanese longliners in the Atlantic

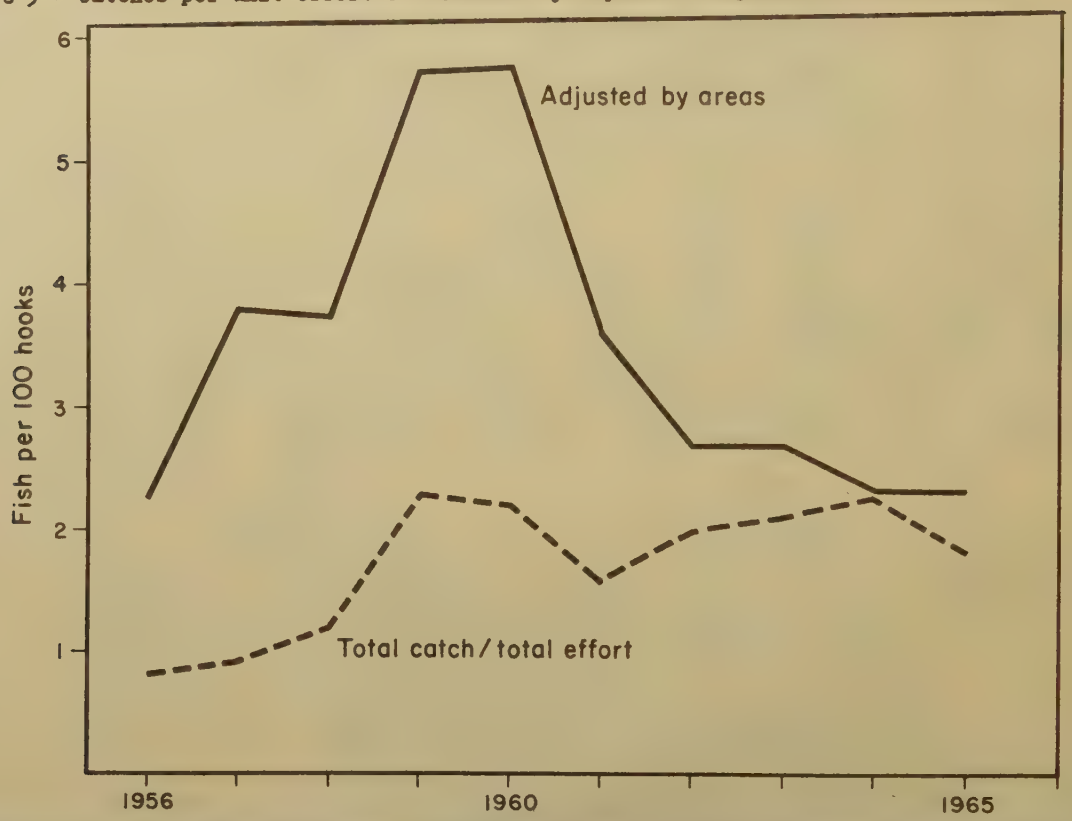
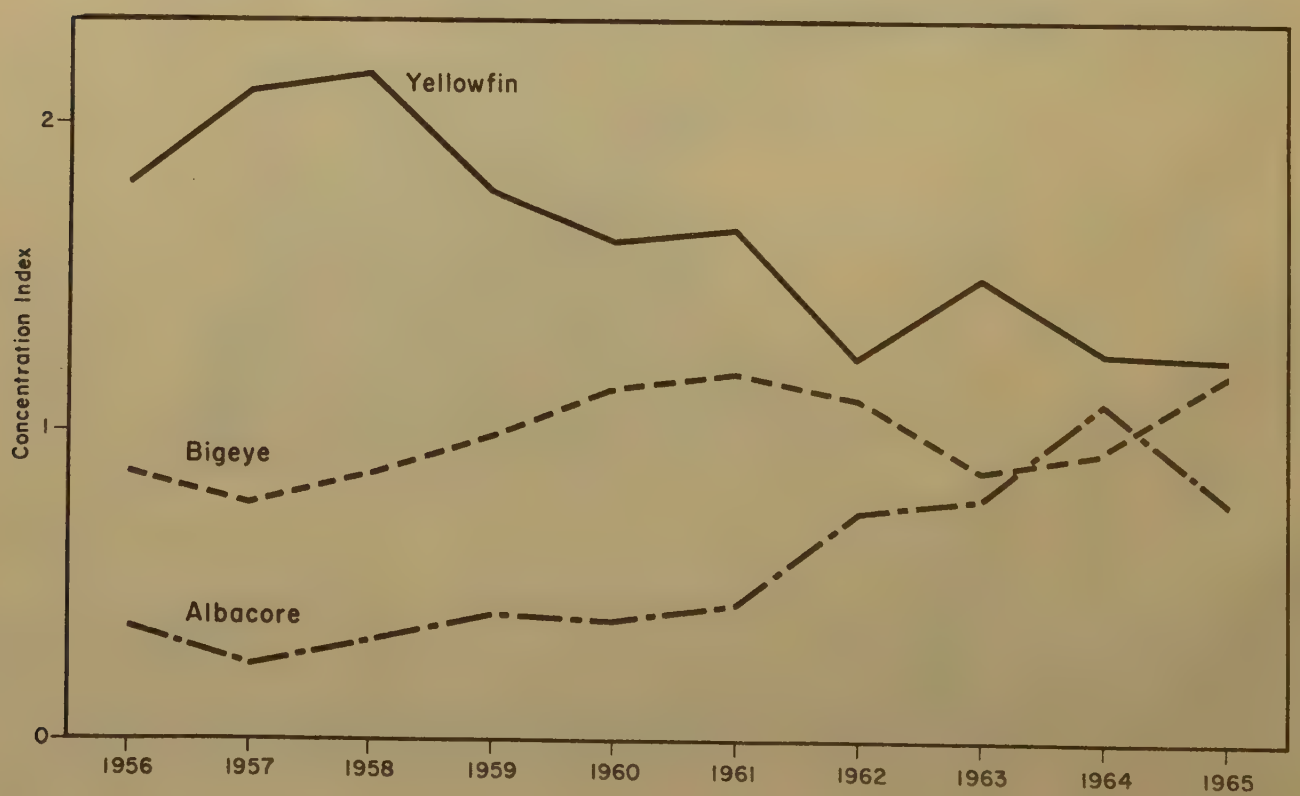


Figure 10 - The concentration index, showing the degree to which Japanese longliners in the Atlantic concentrated in the areas of highest abundance, for yellowfin, bigeye and albacore (from Koto et al.)



Although statistics of total catch are available for the surface fishery in the Bay of Biscay, effort statistics are not yet available. The remarks concerning errors in statistics of catch and effort of yellowfin tuna in section 2.2.2 also apply for albacore.

2.3.3 Biological Data

Growth data from Yang et al. (M.S.) gave von Bertalanffy growth parameters of:

$L_\infty = 135$, $K = 0.19$

Comparable estimates for the Pacific were:

$L_\infty = 126$, $K = 0.21$

2.3.4 Stock Assessment

Graphs showing the relation between the yearly catch per unit of effort and effort for the Japanese longline fleet by major areas of the Atlantic were presented. All areas of relatively high catch (NOW, BAH, RIO, and FLA), except one (BEN) showed a tendency for apparent abundance to decrease with increasing effort. In the remaining areas of low catch, definite trends were not discernible. When all areas were combined the ratio of total catch to total effort appeared to remain fairly stable (Figure 9 broken line). This was, however, most likely caused by the distribution of effort. Early in the fishery the fleets tended to concentrate in areas where yellowfin were most abundant but later to shift to better albacore areas. A quantitative measure of this concentration can be obtained by calculating the catch per unit effort separately for each small area, and using the average of these separate catch per unit efforts as an index of abundance. Dividing these into the ratio of total catch to total effort gives a figure which may be termed the concentration index. The degree to which this index exceeds unity reflects the degree to which the fleets locate and fish on concentrations of fish. Figure 10 shows the concentration index for yellowfin, bigeye, and albacore calculated from the Japanese longline data. The figure shows the degree to which fishing was initially concentrated on yellowfin, and away from the main albacore areas, and the extent to which this distribution has changed.

Utilizing the information from Figure 10, the catch per effort values were recalculated by dividing the catch per unit effort by the concentration index, to account for the bias introduced by the irregular distribution of fishing effort (Figure 9, full line). Examination of these adjusted figures show a distinct trend in decreasing catch per unit effort since 1959 or 1960 which in the detailed data is most apparent in the southern area. The group believed that in the south the fishing effort has reached a level such that no increase in sustained catch can be expected to result from increased longline fishing. On the other hand, in the northern area fishing does not appear to appreciably affect the stocks over the levels of effort observed in recent years. The group could not make any estimate of the interactions between the surface and longline fisheries.

2.4 Bigeye Tuna

2.4.1 Distribution and Stock Structure (see Figure 11)

Statistics were presented which show that bigeye tuna are distributed widely throughout the Atlantic Ocean between 45°N and 40°S. Immature fish tend to be more concentrated poleward with the mature fish being confined to more tropical latitudes.

Information on the stock separation of bigeye tuna in the Atlantic Ocean is totally lacking.

2.4.2 Review Statistics of Catch and Effort

Catch statistics for the longline and surface fisheries were considered by the group and are shown in Table 5.

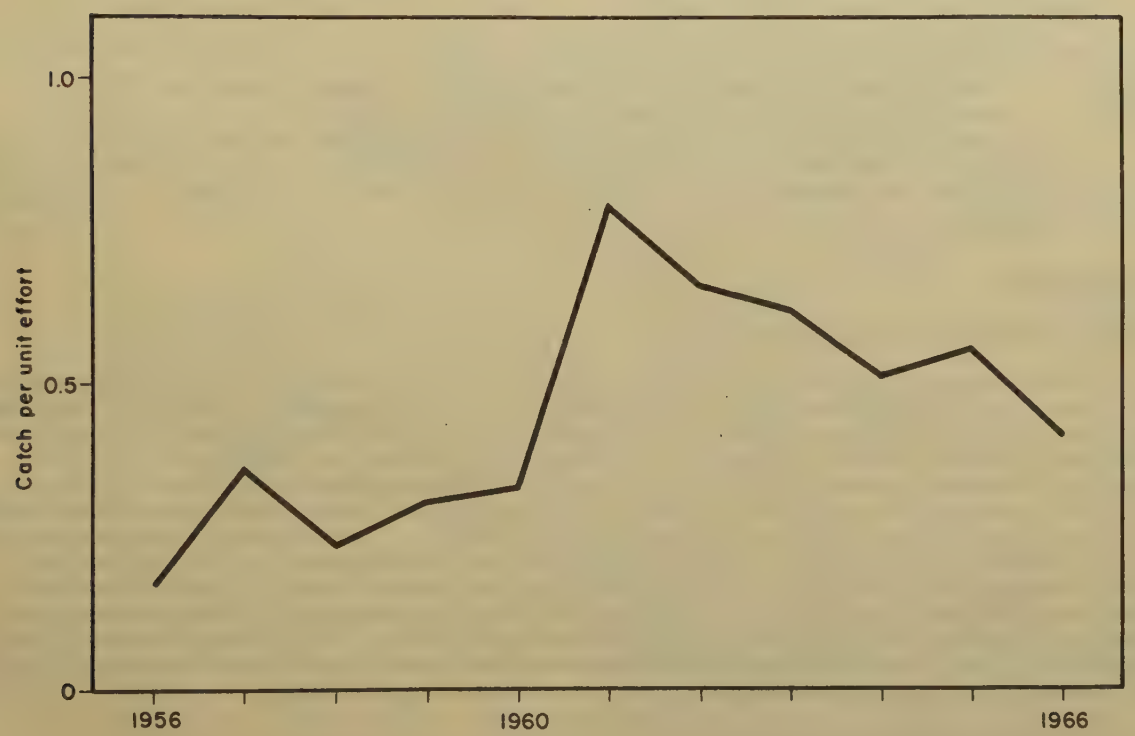
As already noted for yellowfin tuna and albacore, these statistics are subject to error due to double reporting, misidentification of species, etc., though so far as possible these have been corrected here.

2.4.3 Biological Data

Lacking. Information on stock separation, movements, growth, etc. are necessary to provide a sound study of the population dynamics.

Figure 11 - General distribution of bigeye tuna in the Atlantic
(darker shading indicates areas of higher apparent abundance)

Figure 12 - Catches per unit effort of bigeye tuna by Japanese longliners in the Atlantic



2.4.4 Stock Assessment

Bigeye tuna do not contribute as large a proportion to the total catch of tunas from the Atlantic as do yellowfin and albacore. The longline fishing effort appears to have been distributed effectively randomly with respect to the bigeye distribution (Figure 10). Figure 12 (from Kote and Morita, M.S.) showing the catch per unit effort adjusted for distribution for bigeye tuna during the period 1956 to 1966 represents statistics for most of the Japanese longline catch. No clear trend in catch per unit effort is evident though there appears to have been a decrease since 1961. It was not possible for the group to determine just what effect fishing may be having on the stock of bigeye tuna in the Atlantic. However, it is likely that the bigeye are not being too heavily exploited and that current catches can be sustained, and can perhaps be increased to a limited extent by a moderate increase in longline fishing effort.

Table 5. Catches of bigeye tuna from the Atlantic (thousand tons)

	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
Longline	ø	0.4	0.7	2.0	3.2	11.2	17.1	11.6	17.2	32.5	14.8	-
Surface	0.7	2.6	1.2	1.8	1.4	1.1	2.5	2.0	2.6	2.2	3.2	-
Total	0.7	3.0	1.9	3.8	4.6	12.5	20.4	13.8	20.0	35.0	18.0	-

Notes (a) Surface statistics are not at all reliable, since small bigeye are often mixed with yellowfin on the market, and are in fact difficult to distinguish. The figures in the table are mainly of reported Portuguese catches, which include "various tunas". The appreciable quantities of bigeye in the reported yellowfin catches of French vessels off West Africa are not included in the Table.

(b) For further notes see Table 1

2.5 Bluefin Tuna

2.5.1 Distribution and Stock Separation (see Figure 13)

The regions of highest apparent abundance of the large sizes of bluefin tuna taken by the longline fishery are off southern U.S.A. in May and June, off northern South America in April and May, and off West Africa in October, November, and December. In comparison with that of other species, the distribution of bluefin tuna in the longline catches is both patchy and irregular. On occasion very high catches have been observed extending over several 5° squares, which are followed by low catches in the following months, and also in the same months in later years. This variability makes establishment of clear trend in catch per unit effort very difficult. The regions of highest apparent abundance of the smaller sizes of bluefin tuna taken by the surface fisheries are off the United States and off Portugal and in the Bay of Biscay. Large mature bluefin occur in the Mediterranean, and along the coasts of Spain and Morocco, where they are caught in traps and in the northern North Sea. The southern bluefin tuna also occur in the South Atlantic Ocean, but its contribution to the catch is negligible. Much further information on movements and stock separation is required, using for example morphometrics, tagging (especially small fish in the Bay of Biscay), etc.

2.5.2 Review Statistics of Catch and Effort

The catch statistics of bluefin tuna are summarized in Table 6. The same general remarks concerning the nature of the yellowfin statistics apply to the bluefin statistics.

Figure 13 - General distribution of bluefin tuna in the Atlantic
(darker shading indicates areas of higher apparent abundance)

Table 6. Catches of bluefin tuna in the Atlantic (thousand tons)

	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
Surface fisheries											
Western North Atlantic											
-Canada	0.2	0.1	ø	0.1	ø	0.1	0.2	0.7	1.5	0.7	0.2
-United States	0.2	0.5	1.1	1.3	0.6	1.1	3.9	5.6	4.8	3.1	...
Total	0.4	0.6	1.1	1.4	0.6	1.2	4.1	6.3	6.4	3.8	...
Eastern North Atlantic											
-Denmark	0.5	0.6	0.3	0.8	ø	0.2	0.2	ø	0.1	ø	ø
-France	...	5.3	1.4	2.0	0.9	1.5	1.5	1.0	1.6	1.2	2.6
-Germany	0.6	1.3	0.5	1.0	0.4	0.3	0.2	ø	ø	ø	ø
-Morocco	3.6	4.5	10.5	5.0	6.0	2.3	1.6	3.9	4.4	(4.0)	3.5
-Norway	4.1	5.0	3.6	2.5	3.3	8.0	8.0	0.2	1.4	2.5	1.0
-Portugal	...	...	...	...	...	2.8	5.7	6.7	1.0	1.5	0.3
-Spain	12.5	14.8	13.8	9.0	9.8	6.8	10.3	9.7	8.3	9.2	6.6
-Mediterranean (various countries)	...	...	(6.3)	(4.9)	(3.8)	(4.6)	3.8	5.0	5.4	4.5	(3.8)
Total	...	...	(38.0)	(27.0)	(26.0)	26.5	31.3	26.5	22.2	22.9	17.8
South Atlantic											
-Angola	4.0	3.6	3.5	1.5	2.8	2.5	2.4	2.6	4.2	2.3	1.6
-Spain	...	...	...	...	...	...	1.5	0.4	1.3	...	...
Total	...	...	...	...	...	...	3.9	3.0	5.5	...	...
Longline fisheries											
-Japan	ø	ø	ø	0.4	0.8	0.5	6.4	8.0	8.8	8.4	4.2
Total	ø	ø	ø	0.4	0.8	0.5	6.4	8.0	8.8	8.4	5.3
Total - all methods	...	...	(42.6)	(30.3)	(32.0)	30.7	45.7	43.8	42.9	37.5	(28.0)

Notes (a) US totals from 1962 include landings in Puerto Rico

(b) Totals and subtotals include small quantities by countries not specified in the table

For further notes see Table 1.

2.5.3 Biological Data

There is some information in the literature concerning bluefin growth. The size distribution of the bluefin catches is similar to that of the other tunas in that smaller fish are taken in the surface fisheries than in the longline fisheries but large mature fish are also taken in the traps in the Mediterranean and adjacent waters. In the North American surface fishery, bluefin tuna range in length between 50 and 150 cm (between 2 and 50 kg), whereas the fish in the traps and longline fisheries are mostly greater than 50 kg. Some migratory patterns have been deduced from tag returns, viz. migrations from Gibraltar to the Bay of Biscay and from the New England area to Northern Europe; and also from the discovery of harpoons and hooks used in distant fisheries in tuna caught in the Mediterranenan. Examples are given in Figure 14.

2.5.4 Stock Assessment

Accurate assessment of the state of the stocks of bluefin tuna is made difficult by the scattered nature of the fisheries, for several of which no good effort data are available, and by the variability of many of the characteristics of the bluefin population - e.g. distribution and year-class strength. The presence of several distinct fisheries, exploiting different size groups, raises the same questions of the interaction between these fisheries as are discussed in some detail for the yellowfin tuna.

An I.C.E.S. working group has shown a clear decline in the apparent abundance of large, old (6 to 12 years old) fish on which two important European fisheries - off Norway and in the North Sea, and the trap fishery of southern Europe - has been based. The catches from these fisheries have declined very sharply from peaks in 1951 and 1955 (in the North Sea), and since 1958 (Spain and Portugal). It was, however, not possible to show conclusively that this decline was due to heavy fishing; it seems to have been due at least in part to the lack of any good year-classes recruiting to these fisheries since those of 1949, 1950, and 1952.

The large tagging experiments in the western Atlantic surface fishery enables rather firmer conclusions to be reached concerning the effect of fishing on this group of fish. The tagging experiment carried out by the Woods Hole Oceanographic Institute in 1966 gives the following results:

Tagged	Returns in 1966		Returns in 1967	
	Local	Europe	Local	Europe
3956	529	0	581	12

These returns (13% in the season of tagging, and 15% in the next season) suggest an exploitation rate in the fishery $\frac{F}{F+M}$ of at least 28% which may be a considerable underestimate since a comparison of the returns of fish tagged which were initially caught by purse-seine and by sports fishermen suggests a higher mortality at tagging among the purse-seine caught fish. It is therefore considered that this fishery is exploiting quite heavily a group of fish which is not very abundant. Further, adapting the method of Allen (1953), the optimum size at first capture can be determined by comparing this weight with the expected weight in future catches obtained by releasing these fish, equal to the exploitation rate times the mean weight in the catch. Taking the average weight of fish in the catch as 35 kg, a 28% exploitation rate implies that the capture of fish smaller that 35 x 0.28 = 9.8 kg would cause a loss in sustained yield. The group believes that this is likely to be an underestimate of the optimum size at first capture, and that pending better assessments, the capture of bluefin less than 10 kg in the commercial fishery should be discouraged.

2.6 Skipjacks

Skipjacks are apparently widely distributed throughout the Atlantic Ocean as is evidenced by sightings and larval distribution. Surface fisheries are prosecuted in the area off West Africa and waters off Cuba , and very recently off the eastern United States of America.

Present catches are small compared with those of other tuna.

Information on the biology and population dynamics of skipjack tuna in the Atlantic is lacking. It is likely, however, that this species is under-exploited and could support larger catches.

Figure 14 - Movements of bluefin tuna, as shown by tagging

3. INDIAN OCEAN

The data on the stocks of tunas in the Indian Ocean were considered in order to bring up to date the tuna oriented sections of the 1967 IPFC report on the state of fisheries and assessment of potential resources of the Indian Ocean and adjacent seas. Charts showing the general distribution of the major species are given in that report and are not repeated here. Data on the catches and effort by Japanese longliners are available for two more years (1965 and 1966), and the trends in total catch of the four main species caught by Japanese longliners are shown in Figure 15 (from Kikawa et al., M.S.).

3.1 Yellowfin Tuna

3.1.1 Distribution and Stock Separation

The greatest apparent abundance of longline-caught yellowfin tuna in the Indian Ocean occurs along the Equator from about lat. 5°N to lat. 13°S. In addition, the apparent abundance tends to increase from east to west.

There is no clear discontinuity in the catches per unit effort across the Indian Ocean, but in different areas there are different patterns in the change of catch per unit effort with time, which might suggest some separation of stocks. In the Pacific Ocean, and also in the Atlantic, as reported above, movement of yellowfin seems to be limited relative to the total distribution of yellowfin in each ocean. Probably the same is true of the Indian Ocean, and in this report catch and effort data for three areas (40° - 70°E, 70° - 100°E and 100° - 130°E) are considered separately.

3.1.2 Review Statistics of Catch and Effort

Catch and effort statistics for the Japanese fishery are given in the IPFC report (M.S.). These are brought up to date by Kikawa et al. (M.S.). The few additional years of data do not materially affect the IPFC group's interpretations that the fishing intensity "may be close to the maximum level for rational utilization", but longline fishing for yellowfin in the Indian Ocean by countries other than Japan, during the years subsequent to the IPFC report, has tended to increase sharply. This increase is based on reported Indian Ocean catches of yellowfin of 4,600 tons by China (Taiwan) in 1967. Korean catches of all tuna in the Indian Ocean were 750 tons in 1966, and 3,600 tons in 1967. In addition to the recorded catches there is some evidence to indicate that Chinese (Taiwan) fishermen may have caught significant quantities of yellowfin tuna during the 1960s. The problem of unrecorded catches of yellowfin tuna in the Indian Ocean requires further study.

3.1.3 Biological Data

There is little biological information pertinent to the dynamics of yellowfin tuna in the Indian Ocean. The information is summarized in the IPFC report.

3.1.4 Stock Assessment

A striking characteristic of the yellowfin tuna statistics for the Indian Ocean is the dramatic decline in longline catch per unit effort since 1952 (see Figure 16) from Kikawa et al. (M.S.). This decline appeared to be much greater in the western Indian Ocean than in the eastern Indian Ocean. The decline in catch per unit effort to about a quarter of its initial value, which was correlated with increasing fishing intensity, and a non-increasing total catch provided rather clear evidence that application of additional units of effort in the longline fishing directed at yellowfin would not produce increased catches. The possibility that increased catches of yellowfin could be derived from the yellowfin group(s) in the Indian Ocean by developing surface fisheries for the rather smaller yellowfin, as in the eastern Atlantic and Pacific Oceans, was considered. The group acknowledged that the location of large surface concentrations of smaller yellowfin in the Indian Ocean was unknown. Also the balance, in terms of total catch, between placing fishing emphasis on the smaller surface fish, and on the larger yellowfin taken by longline, was determined by various population parameters, and it is not yet known to what extent these rates for the yellowfin in the Indian Ocean differ from those for yellowfin in the other oceans. Further studies on this are required.

3.2 Albacore

3.2.1 Distribution and Stock Structure

In the Indian Ocean albacore are distributed principally south of the Equator as reflected by catches from the longline fishery. Large mature fish occur principally north of 30°S and

Figure 15 - Catches of tuna in the Indian Ocean by Japanese longliners (from Kikawa et al.)

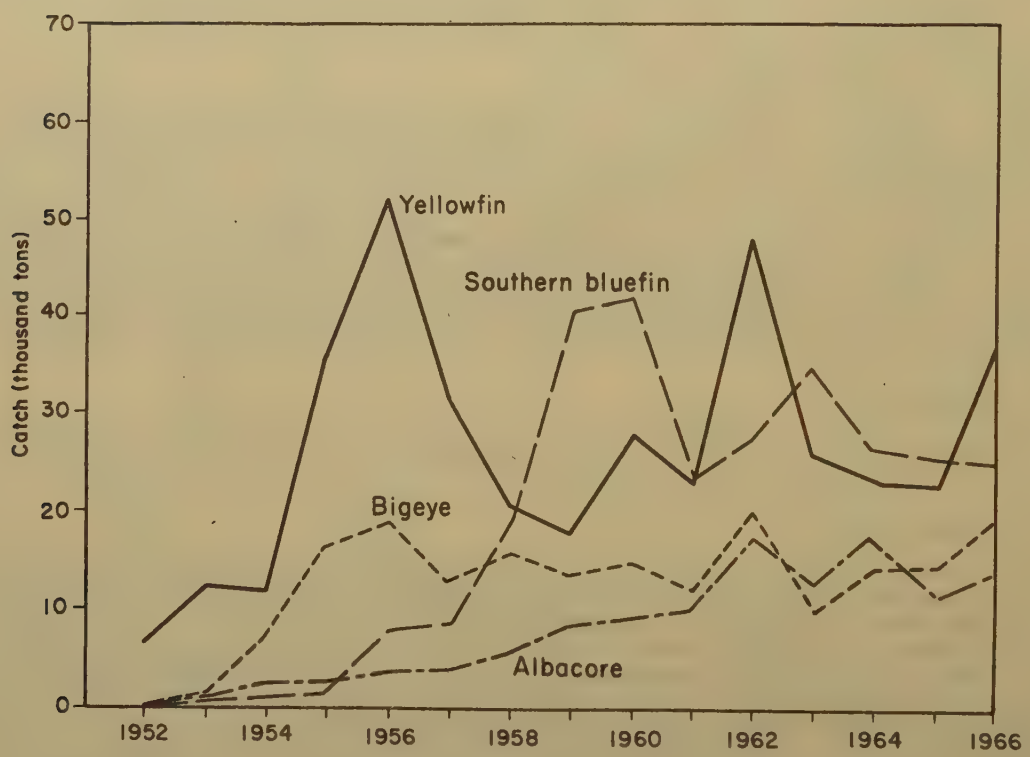
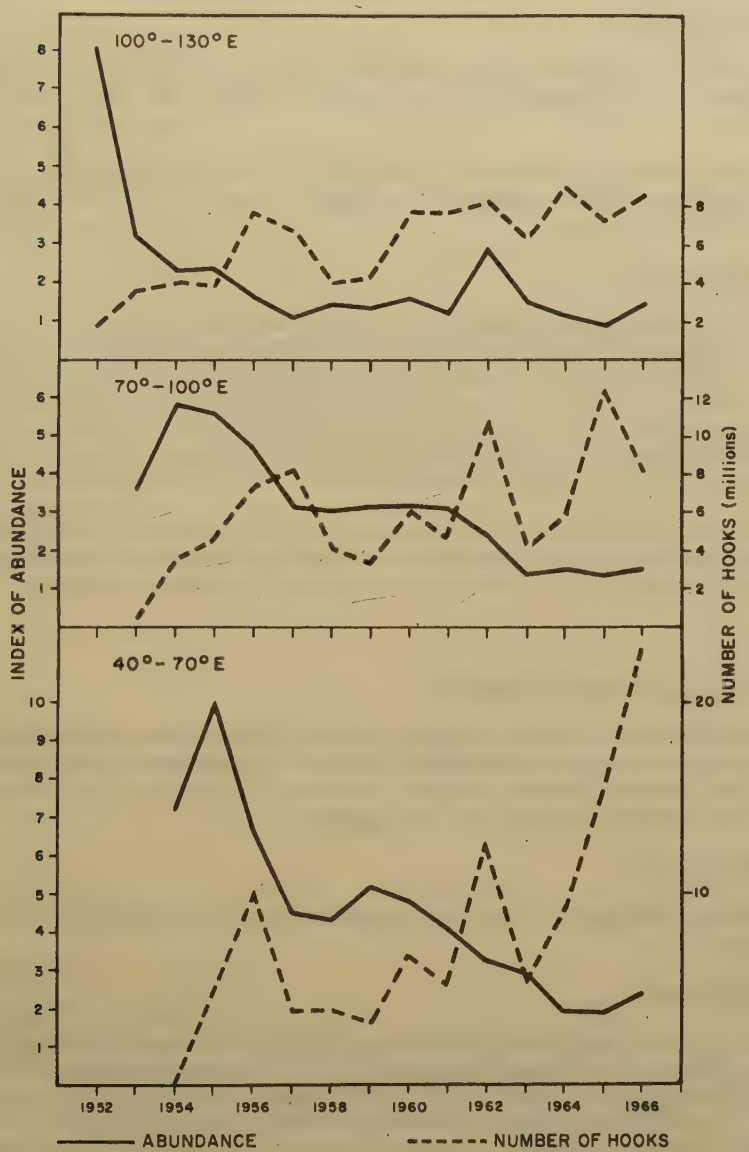


Figure 16 - Catches per unit effort of yellowfin tuna in the Indian Ocean by Japanese longliners (from Kikawa et al.)



smaller immature fish below this latitude. During the southern summer, the highest concentrations of fish appear to be taken in the southwestern portion of the Indian Ocean and in the southern winter the highest concentrations are located nearer the Equator.

Catch statistics do not suggest heterogeneity within the population of albacore fished in the Indian Ocean, though blood group information does suggest some heterogeneity. Only rather limited blood group data have so far been examined, so that conclusions drawn from them should be considered only tentative. The distribution of catches also suggests strongly that intermingling of albacore occurs between the Indian and Atlantic Oceans.

3.2.2 Biological Data

The size range of albacore taken by the longline fishery in the Indian Ocean is approximately the same as the size range from the Atlantic Ocean. The model size is however somewhat lower in the Indian Ocean.

Albacore with mature gonads are taken in the western Indian Ocean between 10°S and 30°5 S and in largest numbers in the southern summer. Larvae are found throughout the year between 10 and 26°S from Madagascar to the Sunda Islands.

3.2.3 Stock Assessment

The group examined graphs showing the catch per unit of effort and catch for the period 1953/66. The apparent abundance of albacore has declined from approximately 3.5 fish per hundred hooks in 1954 to about 1 fish per hundred hooks in 1966 (Figure 17) from Kikawa et al. (M.S.). This clearly reflects the effect of fishing on the abundance of albacore. Since the inception of the fishery in 1952 catches of albacore rose to approximately 18,000 tons in 1962 (see Figure 15). Since that time they have remained fairly stable. Size composition data, which show a decrease in the proportion of larger fish, tend to support the conclusion that the albacore stocks are heavily fished.

The group concluded that the level of exploitation of the albacore stocks in the Indian Ocean was so high that any further increase in fishing on the stocks exploited by the longline fishery will not lead to any appreciable increase in total catch, and may decrease the catch.

3.3 Bigeye

3.3.1 Distribution and Stock Structure

The distribution patterns of bigeye tuna were discussed in the IPFC report and recent information does not alter the conclusions presented there. The greatest concentrations appear to be between the Equator and 10°S in the eastern Indian Ocean and between the Equator and 15°N in western Indian Ocean. Information on stock separation is lacking.

3.3.2 Biological Data

No additional biological data are available apart from those which were presented in the IPFC working group report.

3.3.3 Stock Assessment

The adjusted catch per hundred hooks and effective number of hooks fished are shown in Figure 18 for the years 1952 to 1966 (from Kikawa et al.). The catch per unit effort shows a general decrease since the inception of the fishery in 1952, although relatively not so great as that for the other species. Figure 19, which depicts the relation between catch and effort for the same series of data, reflects a general increase in catch at lower levels of effort with some possibility that catches may be approaching a maximum during recent years.

It was the opinion of the group that bigeye in the Indian Ocean are most likely not being over-exploited and that it is probable that at least a moderate increase in the longline fishing effort will result in an increase in the total catch.

3.4 Southern Bluefin Tuna

3.4.1 Distribution and Stock Separation

The catches of southern bluefin tuna are confined primarily to the waters near Australia,

Figure 17 - Catches per unit effort of albacore in the Indian Ocean by Japanese longliners (from Kikawa et al.)

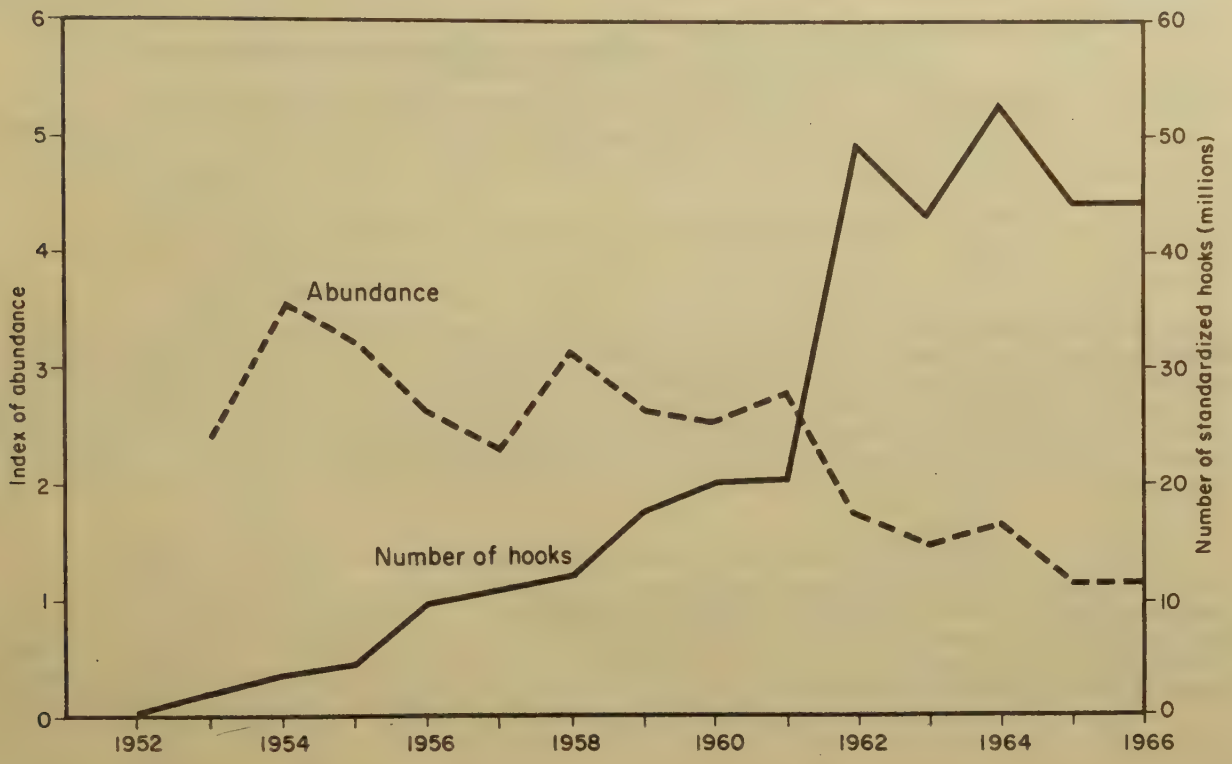


Figure 18 - Catches per unit effort of bigeye tuna in the Indian Ocean by Japanese longliners (from Kikawa et al.)

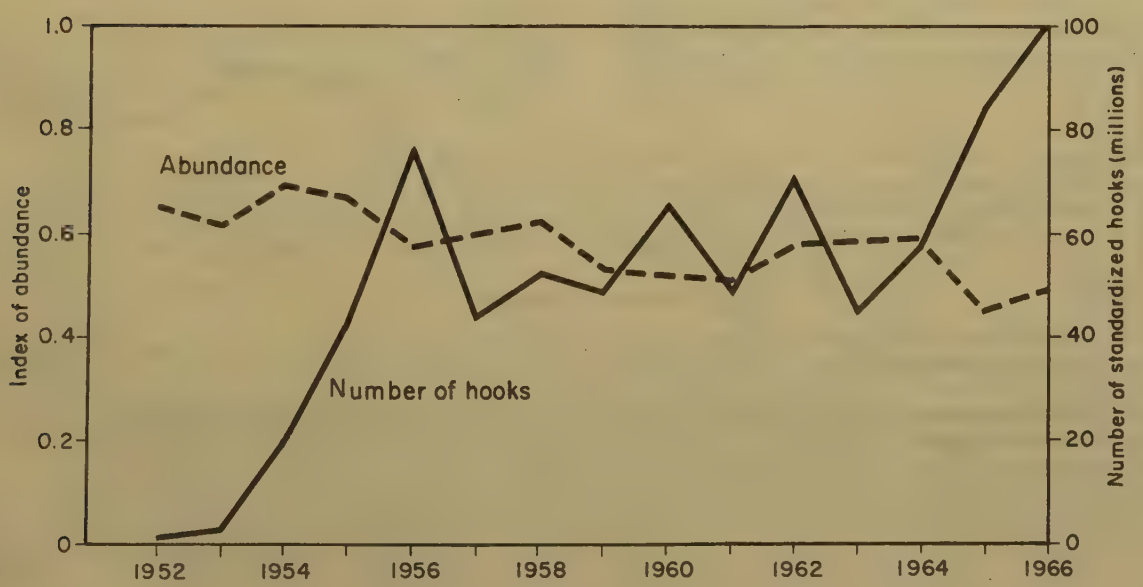


Figure 19 - Relation between total catch and fishing effort on bigeye tuna in the Indian Ocean (from Kikawa et al.)

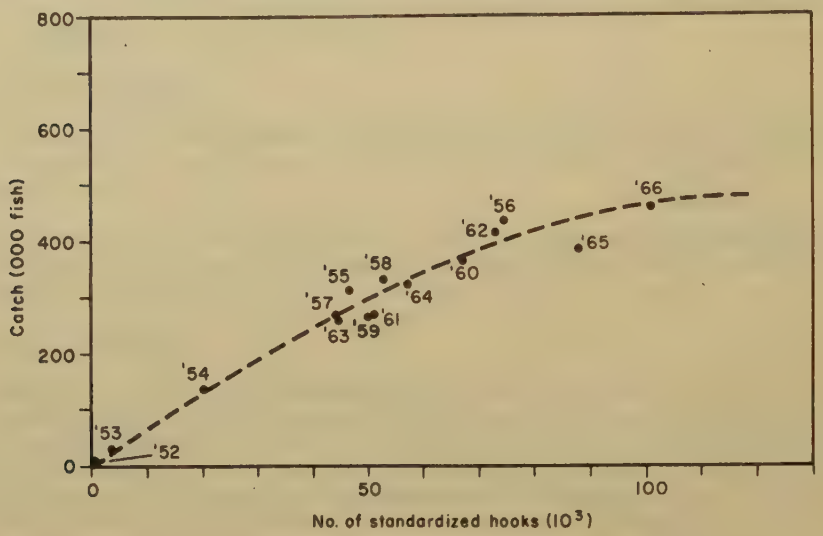
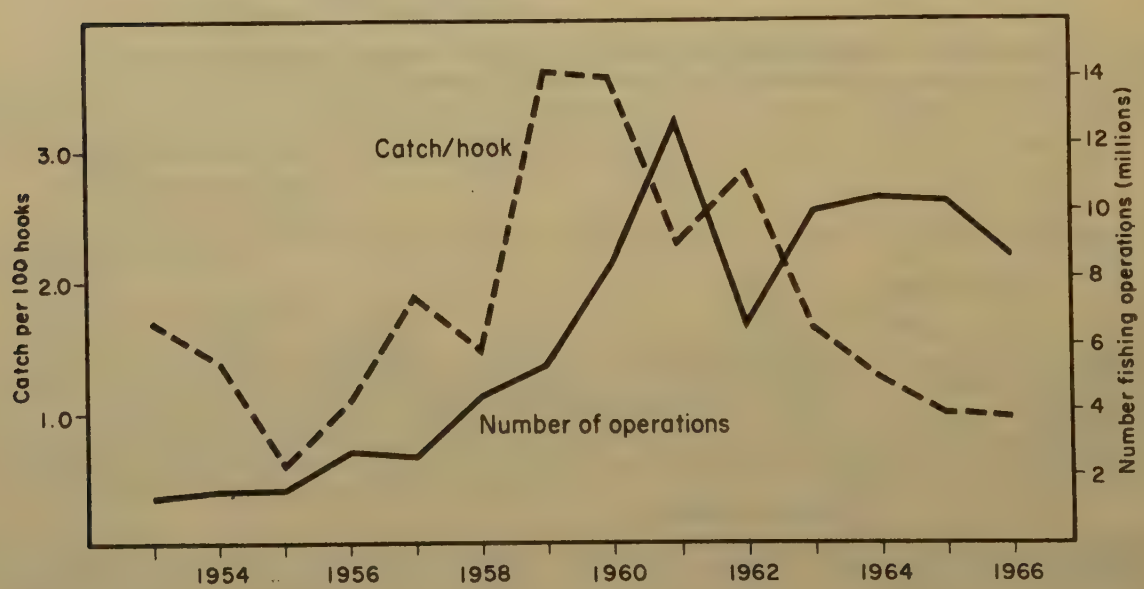


Figure 20 - Catches per unit effort of bluefin tuna in the Indian Ocean by Japanese longliners



west to about long. 90°E. There is also a secondary concentration of bluefin to the south of Madagascar. There is no evidence to indicate more than one stock of bluefin tuna in the Indian Ocean, though Australian studies have suggested the existence of separate sub-groups within the group exploited by the Australian fishery.

3.4.2 Review of Catch and Effort Statistics

The trends in the total catch of Japanese longliners are shown in Figure 15; the catch per unit effort and total effort (from Kikawa et al.) are shown in Figure 20.

3.4.3 Biological Data

There are no additions to the material in the IPFC report.

3.4.4 Stock Assessment

The decrease in longline catch per unit effort since 1960, which followed the rapid increase in total effort after 1957, suggests that the stocks subject to the present longline fishery are heavily exploited. Fishing has been concentrated mainly on the eastern side of the Indian Ocean, and in the absence of data, particularly on stock separation, the group was unable to estimate to what extent, if at all, the total catch might be increased by increased longline fishing in the more western areas. The interaction between the longline fishery, and the Australian surface fisheries, whose catches have increased from around 1,000 tons in 1959 to nearly 8,000 tons is also unknown.

3.5 Skipjack

There is no major fishery for skipjack in the Indian Ocean (the total catch may be of the order of 5,000 tons), and quantitative information on which precise estimates of the resources may be based is lacking. However, skipjack larvae have been found over large areas of the Indian Ocean, and comparison with other oceans suggest that the resource is large. Certainly the present small catches can be increased, but the group emphasizes the need, as the fishery develops, for information on the stocks to be kept under review, so that overexploitation can be avoided.

4. PACIFIC OCEAN

The group did not study the state of the stocks of tuna in the Pacific Ocean in detail. The Pacific tuna fishery is based on the same species and largely carried out by the same countries (and indeed, sometimes the same vessels) and supplies the same market as the Atlantic and Indian Ocean fisheries. It is therefore unrealistic to consider any one of these oceans in isolation as regards statistics, scientific research or management.

The group also noted that the stocks of tuna supporting the longline fishery appear, in general, like those on the Atlantic and Indian Oceans, to be heavily exploited, and that probably the greatest opportunity for substantial increase in the Pacific tuna catch is provided by skipjack. The need for management of the Pacific tuna stocks is probably not less urgent than the need in the Atlantic and the Indian Oceans.

The group, therefore, recommends that bearing in mind this need, as well as the need for adequate statistics and research in the Pacific, the possible advantages and disadvantages of close coordination of the activities in all three oceans should be borne in mind when making arrangements for the collection of statistics research, and management in the Atlantic and Indian Oceans.

5. STATISTICS

Complete statistics on total catches, and good representative samples of catches and corresponding fishing effort are essential for accurate and reliable stock assessment. The statistical data for many of the world tuna fisheries are very far from being satisfactory. Although the statistical and other information available to the group are believed to be sufficient to support the tentative conclusions concerning the state of the stocks presented in this report, to a considerable extent this has only been possible because the members of the group have been able to amend the nominal statistics in the light of their personal knowledge of the fisheries. The statistics presented in this report have been corrected for the types of errors noted below as far as was possible in the light of the knowledge of the members of the group.

The group, therefore, strongly recommends that one of the first tasks of the International Commission for the Conservation of Atlantic Tuna, and of the appropriate body in the Indian Ocean, must be to ensure the collection, tabulation, and prompt dissemination of adequate statistical information.

During its work, the group noted the following examples where the available statistics were actually or potentially misleading:

Total landings - Much tuna is landed in one country by vessels of a different country, often for immediate export to a third country. This has led to duplication and omissions. This situation is known to have occurred as follows:

French vessels landing in West African ports,
Japanese vessels landing in South American ports,
U.S. vessels landing in Puerto Rico,
and possibly also Korean and Taiwanese vessels.

These duplications and omissions should be in principle avoided if, in accordance with recommended practice (c.f. FAO Fisheries Circular 174), catch statistics, for the purpose of compiling statistics for total world catch, or total catch in a given area, are recorded according to the nationality (flag) of the fishing vessels. In addition, statistics according to the port or country of landing are often useful in studying particular fisheries, though for such studies details on area of capture, as noted below, are likely to be more useful.

Species composition - Many of the available reported statistics explicitly group two or more species together, or fail to state that such groupings have occurred (e.g. through failure to distinguish the species by the fishermen or the market), or actually misidentify species. Examples of this are the lack of any species breakdown among some Korean statistics, confusion between small yellowfin and bigeye in West African surface fisheries, inclusion of other species with skipjack in Spanish statistics, possible confusion between skipjack and little tuna or blackfin tuna in some South American statistics, etc.

Area of capture - A minimum requirement for stock assessment is that the area of capture should be known with sufficient precision for all catches to be allocated to the correct stock. In addition, more detailed statistics are often needed for other biological purposes, e.g. studying the effect of environmental factors. Details of such requirements are set out in the reports of FAO Expert Panel for the Facilitation of Tuna Research.

The statistics of two of the major fisheries in the Atlantic - the Japanese longline and the French surface fishery - already do or soon will fulfill these requirements. Several of the other fisheries do not extend over a sufficiently wide area for detailed area statistics to be important. There are, however, no detailed area statistics generally available for the very extensive and important longline fisheries from the Republic of Korea and China(Taiwan), or of the surface fisheries by Spanish vessels.

Effort data - The only reliable effort statistics extended over more than a very few years for a major tuna fishery in the Atlantic or Indian Oceans are those for the Japanese longline fishery. Effort statistics are necessary for all important fisheries.

The corrections of these and other inaccuracies and shortcomings require detailed knowledge of the fisheries, and would be best done by direct investigations at the landing places. Because tuna are only landed at a limited number of places, such investigation would only require limited manpower. The group noted that these problems are common to the Atlantic, Indian, and Pacific Oceans, and might therefore be suitably tackled by a single central organization. FAO would be well competent to do this, provided FAO would be able to provide the necessary manpower, particularly for periodic visits to the fishing ports for the purposes of coordinating the activities of personnel stationed there for the collection of statistics by the governments, or other entities, concerned.

6. DISCUSSIONS AND RECOMMENDATIONS

The group did not have time for any lengthy discussions regarding the requirements for future research, so that the following suggestions, made at various times during the meeting, and also by correspondence between members, must be regarded as tentative, and far from complete.

6.1 Statistics

These are discussed in detail in the previous section.

6.2 Stock Separation

To the extent that several tuna fisheries (especially those by longliners) extend fairly evenly over most of the range of the species concerned, the problem of stock separation is not as important as it might otherwise be. However, for some species, e.g. Atlantic yellowfin, important fisheries are confined to one side of the ocean, and knowledge of stock separation is critical. Tagging and morphometric studies have been suggested earlier to resolve this question. Tagging is of course also useful in giving at least an indication of growth and of mortality rates.

6.3 Age-composition data

Direct age determination is only possible for a few species and sizes of tuna, but age determination from size frequencies is, however, also often possible for most species over much of the size-ranges in the fisheries. Where it can be obtained, regular information on age-composition is for stock assessment work, only less important than accurate statistics, providing estimates of mortality rates, changes in recruitment, yearclass fluctuations, etc. Greatly increased regular age sampling is most desirable where age-determination, by whatever means, is practicable. Also the techniques of age determination deserve further investigation where they have not been fully worked out, but where there is some promise of success.

6.4 Length-composition data

When age-composition data cannot be obtained directly, length data can often be used for the same purposes. Length data are particularly valuable when a wide range of sizes are taken, and when different sections of the fishery take different sizes. Thus length data are invaluable when studying the interactions of the surface and longline yellowfin fisheries. Present length data are extremely inadequate, in terms of total numbers sampled, and of coverage of different fisheries. Improved sampling for length composition should have high priority, especially when, as in many fisheries, length data are comparatively easy and cheap to collect. In collecting and reporting length data the recommendations of the EPFTR working group on tuna length measurements should be followed.

6.5 Stock and Recruitment

While the question of the true relation between adult stock and subsequent recuitment is of major importance, it is at present impossible to suggest specific items of research to be carried out or types of data to be collected which would resolve the problem in the immediate future. All available empirical data on stock and recruitment (not confined to tuna) should be examined to see if any clear pattern emerges (especially one fitting one of the theoretical models which have been suggested). Probably the examination of empirical data alone will not give any conclusive answer, and the solution will require a proper detailed understanding of the factor controlling recruitment, and this understanding is likely to require information on such things as the growth and mortality of young tuna (especially larvae), their food requirements, etc.

6.6 Other Recommendations and Proposals

The following recommendations and proposals were made, and are explained in detail, in the relevant earlier sections:

1. Further studies are required of the stock separations of yellowfin in the Atlantic (sec.2.2.1)

2. The minimum size of yellowfin caught in the surface fishery should not be decreased (sec. 2.2.7)

3. The stock-recruitment relation needs much further study (sec. 2.2.8)

4. The attention of regional commissions is drawn to the possible mixing of albacore and other species between the Atlantic and Indian Oceans (sec. 2.3.1)

5. Pending better assessments of the bluefin tuna fishery of the Northwest Atlantic, the landing of fish less than 10 kg in weight by the commercial fishery should be discouraged

6. The problems of statistics, research and management of tuna in the Pacific are similar to those in the Atlantic and Indian Ocean. These similarities, and the possibility of coordinating activities in all three oceans should be borne in mind in making arrangements in the latter oceans (sec. 4)

7. The available statistics should be improved (sec. 5)

7. SUMMARY

General

The group considered longline and surface fisheries in the Atlantic and Indian Oceans for yellowfin tuna, albacore, bigeye tuna, the bluefin tunas and skipjack tuna. Billfishes were not considered at this meeting but, since they are a significant component of longline catches, should be considered in detail as soon as practicable. Stock separation, catch and effort data, biological data, and the status of the stocks were examined. Certain similarities in the status of the stocks in the Atlantic and Indian Oceans were noted - in fact, there are many parallels with the Pacific Ocean. Preliminary conclusions for the areas of interest follow.

Atlantic

The major Atlantic tuna fisheries are the longline fisheries, chiefly for yellowfin, albacore, and bigeye, which now cover most of the tropical and temperate waters of the Atlantic, and surface fisheries (mainly purse seine and live bait) for yellowfin, skipjack, and bigeye tunas along the West African coast, and trolling and live bait fishing in the region of the Bay of Biscay for small albacore and bluefin tuna. The Japanese longline fishery started in 1956 and the effort by this fishery increased continuously until 1966; some decrease in Japanese fishing in most recent years has been offset by increased fishing by longliners from the Republic of Korea and China (Taiwan). The longline fishery initially concentrated on yellowfin, but later, as yellowfin abundance decreased, attention was transferred to albacore. The effort in the surface fisheries is also increasing, the French and Spanish vessels being joined by vessels from the USA, Japan and West African countries.

The stocks of large yellowfin on which the longline fishery is based have been greatly reduced by fishing. Any further increase in longline fishing would at best increase the total longline catch only marginally and might possibly decrease the total longline catch; further, increased fishing will certainly continue to decrease the catch per unit effort.

The surface yellowfin fishery is based on smaller fish. This fishery has reduced the recruitment to the yellowfin longline fishery. The presence of the surface fishery may increase the total Atlantic yellowfin catch and is unlikely to decrease it. However, if the minimum size of fish taken in the surface fishery is decreased, the total catch will almost certainly be decreased.

The longline albacore and possibly the bigeye stocks are also heavily fished. Increased longline fishing would give little or no increase in albacore catches, though it may be possible to increase bigeye catches. Increased fishing will certainly decrease the catch per unit effort, particularly for albacore. The relation between the surface and the longline fisheries for albacore in the North Atlantic is unknown.

The bluefin tuna stocks do not appear to be large; the group of small bluefin fished off New England is certainly small and heavily exploited. Less is known for certain concerning the abundance of the group of bluefin supporting the larger fisheries off western Europe.

The skipjack stock appears to be large, and the present small catches can be increased.

Indian Ocean

The history of the longline fishery is similar to that in the Atlantic and the Pacific - increasing Japanese fishing since about 1952, with more recently increased fishing by China (Taiwan) and the Republic of Korea. Initially, the Japanese catches mainly consisted of yellowfin, but now contain approximately equal catches of yellowfin and bluefin, and rather less albacore and bigeye. The major surface fisheries are on the eastern boundaries of the Indian Ocean - for bluefin off Australia, and for yellowfin and other species around Indonesia. Another surface fishery is now developing off Somalia.

The yellowfin stocks in the Indian Ocean are probably independent of those in the Atlantic, but there is apparently some intermixing of albacore, bigeye, and bluefin around South Africa.

The state of the stocks is similar to those in the Atlantic. The stocks of all four species fished by the longliners are heavily fished, and increased longline fishing will not appreciably increase (and may decrease) the total yellowfin, bluefin, and albacore catches, though some increase in the bigeye catches may be possible. Increased fishing will certainly reduce the catch per unit effort of all three species. The effects of the surface fishery for bluefin on the longline fishery is not known.

The major opportunity for increasing appreciably the Indian Ocean tuna catch is for skipjack, and these stocks appear to be large. Increased catches might result from surface fisheries of bluefin and yellowfin, but the group lacked information to examine these possibilities.

Statistics

There is an urgent need for an improvement in the statistics of total landings, species composition, and fishing effort. Because of the nature of the fisheries - long-range vessels and vessels landing in foreign countries - the collection, tabulation, and publication of detailed statistics might be better done for the world as a whole, rather than for each ocean separately. The recommendations in the body of this report and in the reports of the Expert Panel for the Facilitation of Tuna Research give details of the requirements.

APPENDIX 1

AGENDA

1. Adoption of agenda

2. Atlantic

   (a) Stock separation
   (b) Review of statistics of catch and effort
   (c) Biological data (growth, mortality, length composition, etc.)
   (d) Previous studies on the states of stocks

3. Indian Ocean (as for Atlantic)

4. General considerations on the population dynamics of tuna

5. The assessment of the effect of fishing on the stocks of tuna, and of the effect of possible regulation measures

   (a) in the Atlantic
   (b) in the Indian Ocean

6. Recommendations for future work

   (a) collection, tabulation and publication of statistics
   (b) research studies, including suggestions for cooperative studies, and possible future meetings of stock assessment experts

7. Preparation of report

8. Any other business

APPENDIX 2

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APPENDIX 3

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APPENDIX 4

Documents presented to the meeting - a) Complete reports

Note: For simplicity a number of published documents which were presented at the meeting, but which are included in the full bibliography of Appendix 3 are omitted from this list.

Hayasi, S. and M. Honma
Assessment of the yellowfin stocks in the Atlantic Ocean, 1956-1965. Far Seas Fisheries Research Laboratory, Shimizu, Japan

Honma, M. and K. Hisada
Population structure of the yellowfin tuna in the Atlantic Ocean. Far Seas Fisheries Research Laboratory, Shimizu, Japan

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Tuna fisheries with the pole-and-line and purse seine along the western coast of equatorial Africa. Far Seas Fisheries Research Laboratory, Shimizu, Japan

Kawai, H.
On the relationship between thermal structure and distribution of longline fishing grounds of tunas in the intertropical Atlantic. I. Analysis based on isotherms on level surfaces, topographies of thermocline, etc. Far Seas Fisheries Research Laboratory, Shimizu, Japan

Kikawa, S., T. Koto, C. Shingu and Y. Nishigawa
The present status of tuna fisheries in the Indian Ocean - 1968. Far Seas Fisheries Research Laboratory, Shimizu, Japan

Koto, T. and Y. Morita
Annual changes of the relative abundance of bluefin tuna, albacore and bigeye tuna in the Atlantic Ocean based on the catch statistics of Japanese tuna long-line fishery. Far Seas Fisheries Research Laboratory, Shimizu, Japan

Nakagome, J. and I. Mitani
Monthly and annual variation of distribution of sea surface temperature in the tropical Atlantic Ocean. Kanagawa Prefectural Fisheries Experimental Station, Japan

Rothschild, B.J. and M.Y.Y. Yong
1968 Materials for the study of changes in the apparent abundance of tunas in the Indian Ocean, 1952-1965. Prepared at the Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii

Shiohama, T., Y. Morita, Y. Nishigawa and S. Kikawa
An outline of recent changes of the Japanese tuna longline fishery. Far Seas Fisheries Research Laboratory, Shimizu, Japan

Ueyanagi, S. and S. Kikawa
Distribution and relative abundance of billfishes in the Atlantic Ocean. Far Seas Fisheries Research Laboratory, Shimizu, Japan

APPENDIX 4

b) Summaries only

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